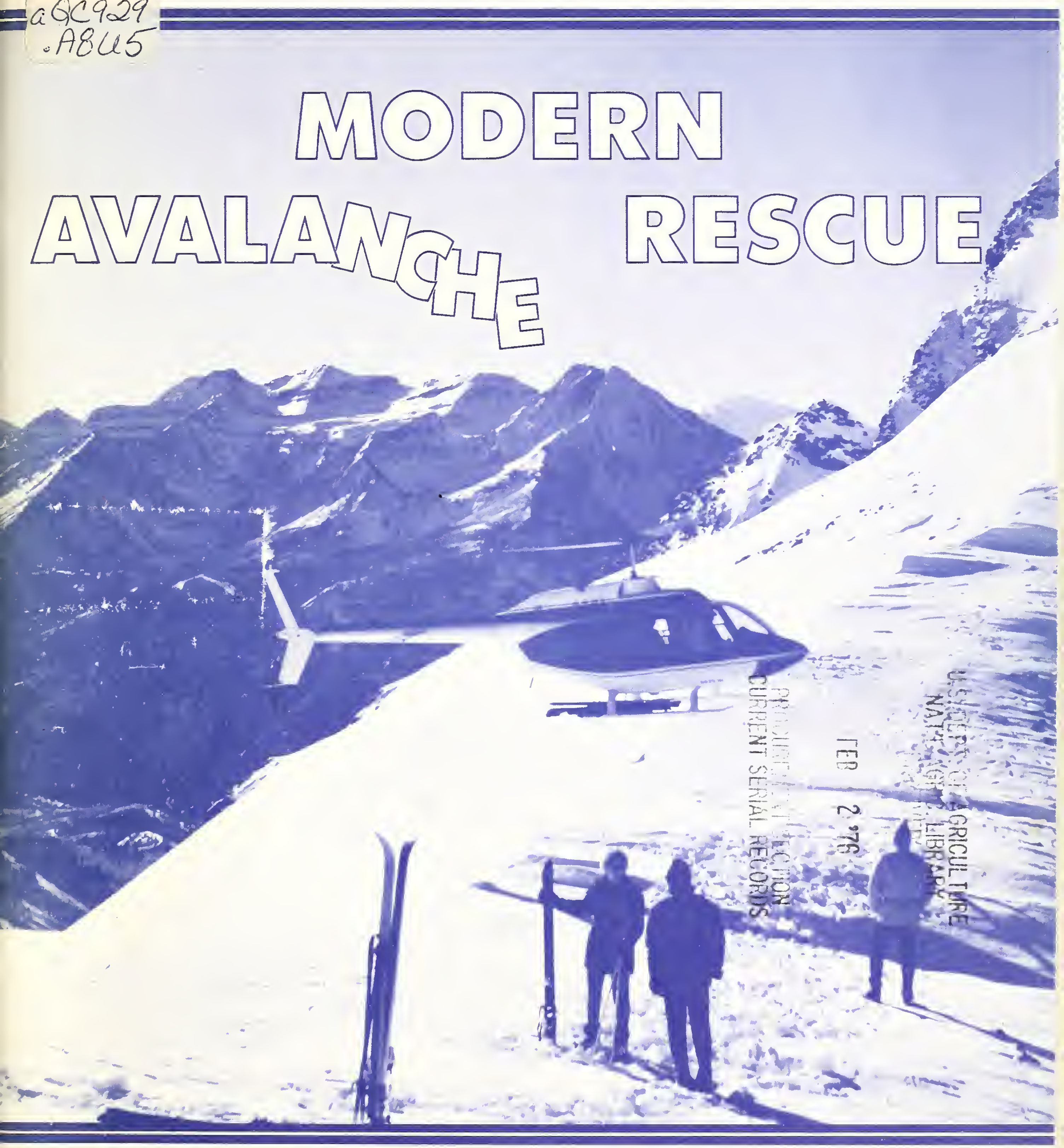
SNOW SAFETY GUIDE NUMBER I

MODERN AVALANCHE RESCUE



U. S. DEPARTMENT OF AGRICULTURE
FOREST SERVICE

WASATCH NATIONAL FOREST
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ALTA AVALANCHE STUDY CENTER

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SNOW SAFETY GUIDE NO. 1

24510

MODERN AVALANCHE RESCUE

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U. S. DEPARTMENT OF AGRICULTURE

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Illustrations by: John Nielsen

The Snow Safety Guides

Since the USDA Handbook 194 "Snow Avalanches" was published in 1961, there has developed an increasing need for additional publications on snow safety. Part of this is the result of new techniques, equipment and policies which have evolved since 1961, and part of the need stems from a steady increase in snow safety problems accompanying the growth of the winter sports industry.

In order to provide thorough and up-to-date treatment of specific topics which received only limited discussion in Handbook 194, the series of publications known as "Snow Safety Guides" has been established. These will, in essence, constitute supplements and revisions of Handbook 194. Various individuals in National Forest Adminstration and Research throughout the Forest Service will contribute material for the Guides. Editorial supervision will be exercised by the Alta Avalanche Study Center on the Wasatch National Forest.

Publication of the following Guides is scheduled for 1968:

Snow Safety Guide No. 1--Modern Avalanche Rescue

Snow Safety Guide No. 2--Instrumentation for Snow and Avalanche Observations

Edward R. LaChapelle
Alta Avalanche Study Center

Introduction

Avalanche rescue operations bring together diversified types of people. Skiers, Forest Rangers and law enforcement officers may be asked to work together. Highway maintenance crews and helicopter pilots may cooperate. Snow Safety Guide No. 1 has been compiled as a common standard of reference for these varied personnel so that efficient and competent rescue operations will result from their coordinated efforts.

The reader's familiarity with the fundamentals of avalanche and avalanche terminology is assumed. The U. S. Department of Agriculture Handbook No. 194, "Snow Avalanches" is recommended as prerequisite reading. Snow Safety Guide No. 1 amplifies and modernizes the treatment of avalanche rescue in Handbook No. 194.

In the European Alps, both the skiing and non-skiing segments of the population are exposed to more extensive avalanche hazard than in the United States. The result has been a continuing evaluation of avalanche rescue techniques. A substantial part of the methodology set forth in this Guide has drawn from the extensive European experience, especially in Switzerland. Particularly useful has been the 1963 Symposium on Urgent Measures for the Rescue of Avalanche Victims sponsored at Davos, Switzerland, by the Eigenmann International Foundation. This European experience has been combined with our own growing experience in avalanche rescue to form the basis of this present manual.

The subject matter will be presented in three sections based on the sequence of rescue operations. Section I discusses preparation for the rescue and begins with pre-accident planning. A three-stage approach to rescues is introduced as the logical revision of the two-stage, Hasty Party-Main Party theme which presently dominates rescue practices in the United States. This more efficient, three-stage approach is made possible by greater availability today of proper equipment and trained personnel at avalanche-threatened areas.

Section II discusses methods of locating a buried victim. Many recent ideas, some new to North American readers, are presented. All of these ideas have been tested in the Alps. The Eigenmann Symposium (Ref. No. 11) and a publication of the Austrian Mountain Rescue Service on avalanche dogs (Ref. No. 2) have both provided valuable material.

Section III discusses current medical opinion concerning first-aid measures; the treatment and transportation of avalanche victims.

1. ORGANIZATION AND EQUIPMENT

1.1 Preparation and Organization

Efficient use of time is the theme emphasized in all rescues. Time is even more critical a factor in avalanche rescues. American and European statistics show that approximately 50% of the victims buried in an avalanche suffocate if not uncovered in an hour or less. (See Figure 1.) Earlier, the time limit for 50% survival was believed to be two hours. Hence, rescue operations were designed to find the victim in two hours or less. A two-stage rescue system was devised: the immediate dispatch of a hasty search party (a fast-moving and lightly-equipped group), followed by the later dispatch of a well-equipped, and often slow-moving, main rescue party. Reliable search of an avalanche accident site by a "hasty" party is essential, but if this does not locate the victim, early arrival on the scene of proper equipment and trained manpower is critical to his survival. In addition to recognition of the one-hour time limit, there are two other developments in North American winter recreation which suggest needed revision of rescue methods:

--The increased exposure of an ever-growing population of winter sports enthusiasts to avalanche hazard. This exposure is augmented further by the increasing size and complexity of modern ski area developments and the introduction of such means of access to mountain terrain as helicopters and motor toboggans.

--The rapidly increasing number of trained personnel competent to execute avalanche rescues, and the provision of modern rescue caches in principal areas of avalanche hazard.

The object of a rescue action is to win the race against a clock that is moving even faster than at first thought--equipment and manpower must be assembled as quickly as possible at the accident site. To achieve this goal, a "three-stage" rescue organization is proposed. The degree to which this model is adhered to, or the older system modified, will depend on the individual area. Regardless of the precise rescue plan to be followed, exacting preparation and organization are needed for any operation which presupposes live rescue rather than recovery of a dead body.

We emphasize preparedness and cite an example. The Parsenndienst, the famed Swiss ski patrol at Davos, dispatches a first column of rescuers, completely equipped with probes, shovels, radios and resuscitation equipment, within 4 to 8 minutes after receiving notice of an avalanche accident. All organized avalanche rescue groups should strive to meet this standard.

1.2 The Rescue Plan

A rescue plan, prepared by the administrators concerned with an area's safety, specifies in concise detail how equipment and manpower are to be coordinated in a rescue operation. The plan must be written in a clear fashion and distributed to the nucleus of rescue personnel and posted at all

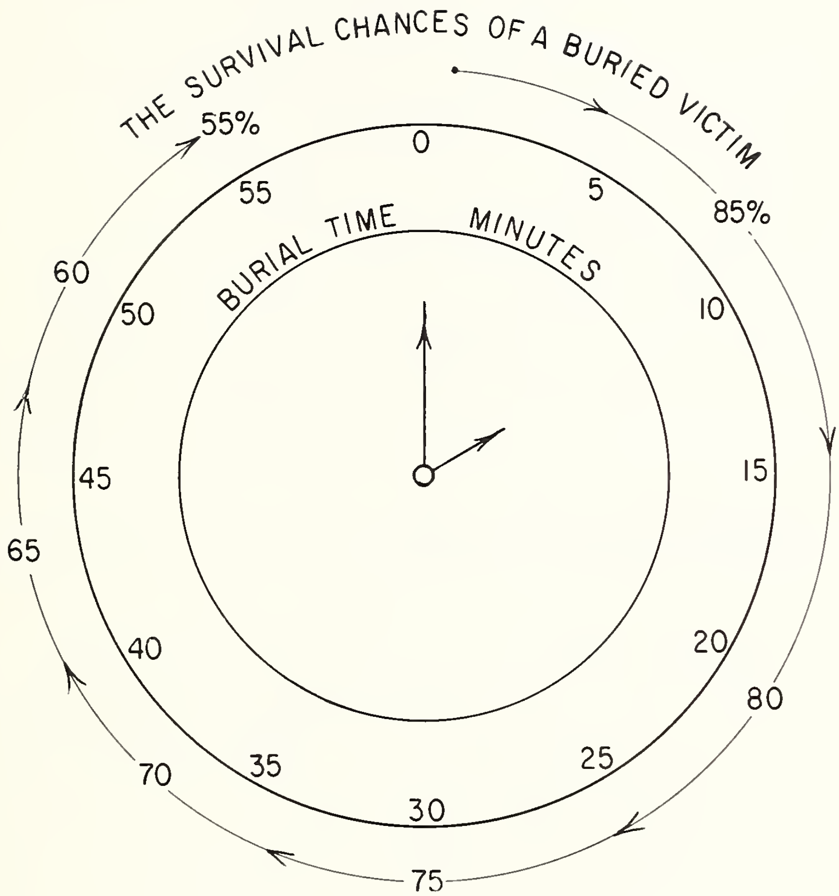


Figure 1. Time is a critical factor in avalanche rescues. The chance that the victim is alive diminishes to about 50% after an hour of burial.

avalanche cache sites. The plan should be reviewed each season and updated as required.

Special features relating to the unique problems of a given area must be incorporated in each plan, but certain essential provisions are common to all plans. These provisions are:

1. Method of initiating the alarm (by whom, and who is notified).

2. Designation of the hierarchy of command.

3. Information about supporting manpower and equipment.

   a. Available manpower--individuals and groups.
   b. Location and inventory of rescue equipment.
   c. Medical and ambulance facilities.
   d. Law enforcement officers.
   e. Transportation, if applicable--lifts, helicopters, etc.

4. Rally points for manpower, ambulance, aircraft.

5. Supplementary information.

   a. Maps of the general area.
   b. Detailed maps of hazard areas.
   c. Job descriptions for group leaders.
   d. Accident record forms.

1.2.1 Method of Initiating the Alarm

The places most likely to receive the first report of the accident must be ascertained. Ski lift terminals, Ranger Stations and Ski Patrol headquarters are the most likely choices, but strategically located concessions such as gas stations and restaurants or lodges should not be ignored. These fixed facilities, along with mobile units such as highway foreman's truck or sheriff's patrol if applicable, are provided with a copy of the written rescue plan and equipped with the means for sounding an alarm or initiating communications. At fixed facilities, such as a ski lift terminal, both visual and sonic alarm systems can be employed. Flags and sirens are popular and effective.

The rescue plan must list clearly and step-by-step the procedure for initiating an alarm. This ordinarily will include notifying the avalanche rescue leader or his designated substitute, who will then assume direction of the rescue and dispatch of the rescue columns. (See 1.2.2 below.) If the initial accident report comes from a location where trained personnel and equipment are available (e.g., ski patrol station), the leader will order dispatch of the first column to the accident scene during the same telephone or radio contact by which the alarm reaches him.

In many states, the county sheriff is the civil officer legally responsible for conducting rescue actions. He has the authority to call up equipment, request manpower and commit public funds in support of a rescue. He must be notified in the early stages of an avalanche accident alarm. Normally this notification is the responsibility of the avalanche rescue leader. The degree of participation by a sheriff's office in avalanche rescue varies widely from one county to another. The sheriff should be contacted and coordination established at the time a rescue plan is prepared.

For areas located on National Forests, the rescue leader should also pass along an early alarm to the District Ranger. Aside from strictly administrative requirements, this opens up another avenue by which such resources as communications, manpower and equipment can be channelled to the accident scene.

1.2.2 Designating the Hierarchy of Command

An avalanche rescue leader is designated at the time the rescue plan is drawn up. In a large ski area, this usually will be a Forest Service Snow Ranger or a Ski Patrol Chief. He assumes complete direction of the rescue until the sheriff or his deputy arrives. In many cases, either by prearrangement or by decision at the moment, he will continue to direct the rescue with consensus of the sheriff's office.

The rescue plan lists in order a number of substitute rescue leaders who will assume command of the rescue in the absence of the designated leader from the area at time of the accident.

The rescue plan also lists men who are competent to assume the tasks of accident site commander and column leaders. In practice, the site commander will often be the next available man on the list of leader substitutes.

The designated rescue leader and his substitutes ordinarily are drawn from the most experienced men in an area. This group may include Rangers, Ski Patrolmen, Ski Instructors, lift foreman or local residents. The rescue leader must be familiar with:

a. Modern avalanche rescue techniques.

b. The local terrain.

c. Location of rescue equipment.

d. Principles of recognizing and avoiding avalanche danger.

e. The rescue plan.

Knowledge of avalanche hazard recognition is sometimes overlooked as a qualification. The rescue leader often is responsible for decisions to send rescue groups into potentially dangerous areas. He must be prepared to make these decisions wisely.

1.2.3 Support Information

The names of ski area administrators, ski instructors and other citizens of nearby communities who are willing to volunteer for arduous mountain rescues should be compiled along with means of contacting them. This list might include as many as 100 prospective volunteers.

Locations and inventories of rescue equipment are listed in detail. For the more complex areas it is necessary to associate specific caches with particular avalanche areas. A complete explanation of cache locations must be given. For example, it may not be enough to describe a cache location as "top of Grizzly Lift." Much better is: "top of Grizzly Lift, under ramp, behind toboggans."

When prearranging medical and ambulance support, place special emphasis on respiratory and other resuscitation apparatus. Designated ambulances must be properly equipped to negotiate mountain roads during periods of storm and avalanche activity.

The participation of law enforcement officers is essential to properly-organized rescue operations. (Note role of county sheriff mentioned above.) State highway patrolmen and highway maintenance crews will often be involved when slides fall on highways. Pre-accident planning and coordination with these groups is essential. Participation of law officers and highway crews in avalanche rescue training is highly desirable.

For accidents at sites other than those directly accessible by ski lifts or roads, the only hope of live rescue often rests on helicopter transport of the search party to the accident scene. A march on foot to back-country accident sites nearly always takes far more time than the critical first hour in which the victim has a reasonable chance to survive. Contacts should be arranged with helicopter services and experienced mountain pilots wherever these are available. If possible, advance arrangements should be made to cover costs of such services in case of accident. Permanent and temporary heliport sites should be known to the rescue leader. In areas where avalanche accidents may be frequent and use of helicopters likely, establishment of avalanche rescue caches at permanent heliports is recommended. See Appendix i for details of a helicopter rescue cache.

1.2.4 Rally Points

When the accident alarm is sounded, volunteers assemble at prearranged primary rally points. Sites with communication facilities, such as lift terminals or Ranger Stations, are the best rally points. Ideally, these should coincide with the location of avalanche caches. Instructions directing volunteers and equipment to the accident site are issued at these primary rally points. For complex hazard areas or widely dispersed ones served by a central rescue organization, secondary rally points may also be designated where the various rescue columns assemble for march to the accident site. Meeting points for ambulances, patrol cars, etc. may also be designated.

1.2.5 Supplementary Data

An ample supply of area maps is essential to the rescue plan. Large-scale topographic maps are preferred; their value can be augmented if principal avalanche areas are clearly marked. Such maps can help an accident witness pinpoint the site, guide the rescue columns, and furnish access information for helicopter support.

Personnel assigned to leadership and communication should be given written job descriptions at the planning stage (don't wait until the accident has happened). For instance, a job description written for the accident site commander would explain how to organize the probing operation, among other things.

Paperwork obviously must be kept to a minimum during actual execution of a rescue. Key personnel must be thoroughly acquainted with details beforehand so they do not have to spend unnecessary time when the rescue is underway performing such tasks as checking cache lists or reading instructions. HOWEVER, there are sound organizational and legal reasons for keeping certain essential records <u>during</u> an accident. The rescue leader, for instance, should have a record of exactly who was sent where, and with which column, so all rescuers can safely be checked back in at the end of the operation. Times of essential decisions and actions should be recorded. Pencil and paper for this should be in the rescue caches or at other critical points.

See Appendix iii for the example of an actual rescue plan.

1.3 Rescue in Three Stages

Most avalanche rescues can be conducted according to a three-stage plan.

Stage I

The first objective is to locate and uncover the victim in the shortest possible time. Sufficient manpower, probes and shovels must be delivered swiftly to the accident site. To insure speed and safety, rescue volunteers should travel in groups of five to ten men, each with an appointed leader. Several such columns may be required during the first stage of a sizeable rescue. Because speed is essential, the columns must carry only those items which will enable them to reach the accident site safely and perform the initial hasty search and probing operation. The rescue leader should issue accurate instructions to each column, including designation of safe routes and an unequivocal appointment of an accident site commander to take charge at the scene.

This First Stage does not eliminate the hasty search function previously programmed in avalanche rescue tactics. The first column on the scene conducts the hasty search of the avalanche debris, scuffing and probing at the most likely burial points. They will also search for clues on the debris surface and mark the location of any which are found. This first column must move out very quickly following notice of an accident; they may

leave much of the rescue equipment for the second and third columns in order to travel at maximum speed. The whole first-stage operation is designed to get probe lines in operation at the accident in the shortest possible time.

During that part of the rescue when the victim's chances of survival are the greatest--the first hour--probing ordinarily will be confined to the coarse-probe technique (see Section 2.3 for details of this technique). Because the coarse-probe line moves with sufficient speed to cover the critical search areas in a short time, it can effectively replace the scuff line. The scuff line has been recommended in previous rescue procedures as a separate step between the hasty search and the fine-probe operation designed to uncover any near-surface clues to the victim's location. The coarse-probe line is able to perform this function while probing is in progress.

Stage II

After dispatch of the hasty search and probe columns, a first-aid and evacuation group is organized. If proper equipment is available, the first (hasty search) column ordinarily will carry a rucksack with elementary first-aid and resuscitation equipment. But this light-weight equipment is intended to deal only with the critical requirements of immediate resuscitation. The second rescue stage is designed to supplement this as soon as possible with more complete first-aid equipment, provisions for sheltering and warming the victim, medical attention if possible, and the necessary equipment for evacuating the treated victim. Equipment transported by the second stage will include toboggans, blankets or sleeping bags, a tent, heating pads, and more sophisticated resuscitation equipment including oxygen and a medical kit for use by a physician.

Obviously the Second Stage may take longer to organize than the first and most certainly will move slower because it is burdened with heavier equipment. But speed is still essential, for the job of rescue is only half done when the victim is located. He still must be revived, protected from shock and further injury, and transported with great care. Accumulating evidence of many avalanche accidents shows that post-rescue treatment of the victim is just as important as finding him in the first place. For instance, if resuscitation is required to restore breathing, the victim must be watched and transported very carefully, with instant provisions to resume resuscitation if breathing stops again.

An important key to a successful (live) rescue is getting expert medical attention to the victim immediately. Ideally a physician should be on the scene when the victim is uncovered. The rescue leader should try to locate a doctor while he is organizing the second column and send him with this column if at all possible. A well-stocked rescue cache ahould include a special medical kit to be used by any available physician. See Appendix i for recommended contents of such a kit.

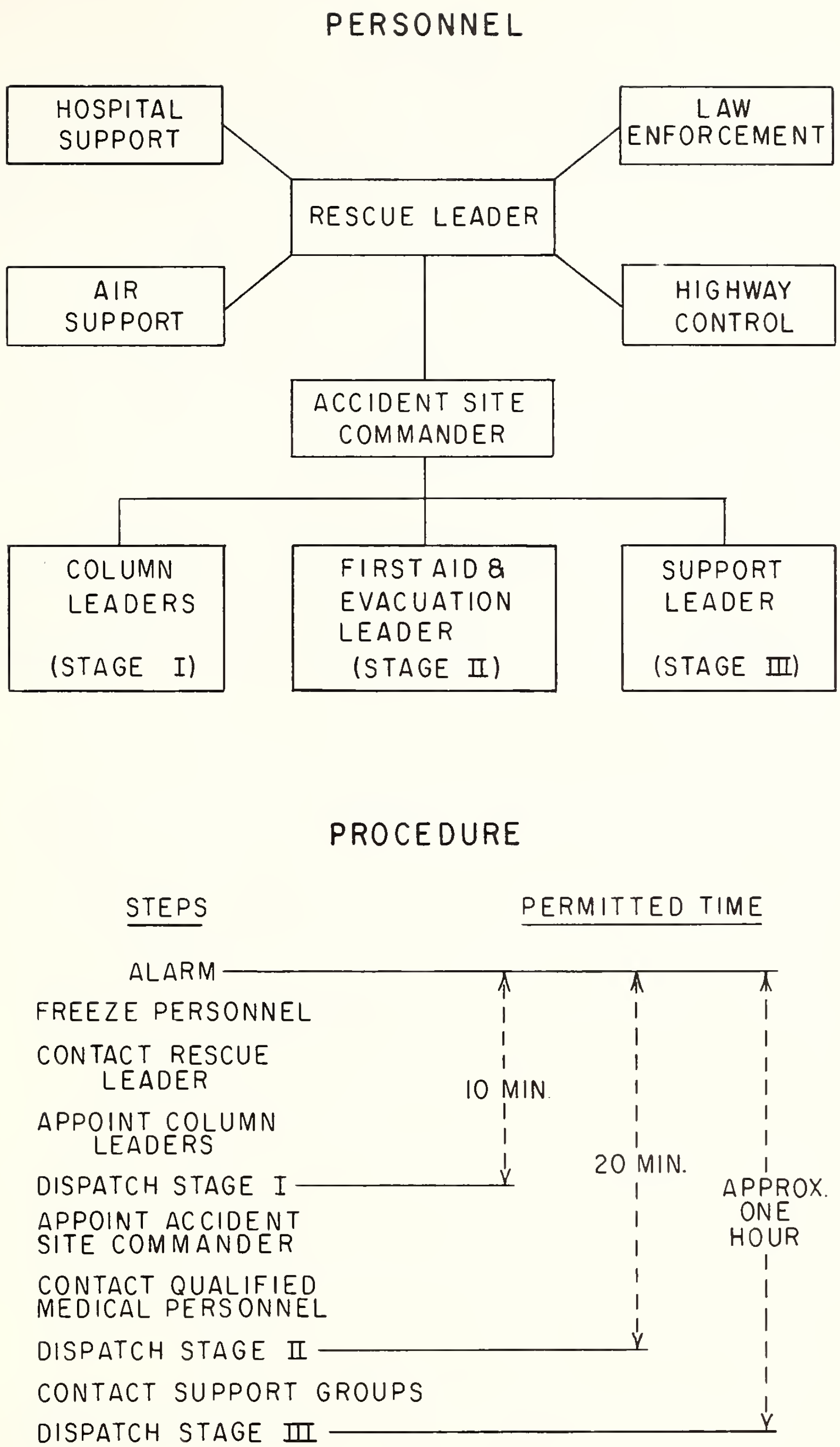


Figure 2. The rescue organization consists of explicit command channels and an operational procedure. Figure 2 is only suggestive; the particulars of the rescue organization would vary from area to area.

Stage III

Speed is emphasized for Stages I and II. As a consequence, volunteers arrive at the accident site with minimum equipment other than that essential for the rescue. If the operation is prolonged, work at night is inevitable. Snowfall, wind and low temperatures are the rule for avalanche rescues. Stage III is the support phase of the rescue. Illumination equipment, food, hot beverage, warm clothing, relief manpower and shelter all lie in the province of Third Stage support operations. With the First and Second Stages dispatched, the rescue leader can turn his attention to alerting civil authorities, calling for extra manpower, and planning the needed additional support. The extent to which the Third Stage is activated will vary widely according to size and distance of the accident. In some cases it may never be necessary. In others, usually prolonged search in major avalanches aimed more at recovering bodies than saving lives, the Third Stage may become the major part of the rescue. Ordinarily the rescue leader will turn to the county sheriff, the Red Cross, organized rescue groups and such agencies as the Forest Service for any extended logistic support. Good communication between the rescue leader and the accident site commander is essential for proper organization of the Third Stage and delivery of the proper resources at the proper time. Poor communication can easily lead to either over- or undercommitment of logistic support during the Third Stage.

The rescue leader obviously is a man with his hands full. Whenever possible, he will designate an assistant to act as communications and liaison man. Because speed is so critical to avalanche rescue, the immediate dispatch of the First Stage takes precedence over other procedures. Once this is done, the rescue leader has to notify the sheriff, District Ranger, other law officers, arrange communications, call on helicopter support, locate a doctor, get the Second Stage underway, and plan ahead to the Third. A judicious delegation of jobs to an assistant and other responsible persons will greatly simplify the rescue. (See Figure 2.)

1.4 A Ski Area Rescue

Description of a hypothetical rescue may clarify the foregoing procedures. A ficticious ski area is shown in Figure 3. An avalanche, designated Accident 1, occurs just east of the upper terminal of Lift No. 2 at 1500 hours. A lone skier is buried. A witness skis down from the accident scene and reports the accident to the lift operator at A (time 1505). The rescue proceeds as follows:

1. The operator at A sounds the avalanche alarm.

2. All lift operators at A, B, and C hold available manpower at their respective terminals. The ski lifts are cleared for conveyance of rescue personnel.

3. Operator at A attempts to contact the rescue leader. The leader is reached at 1507 and he directs the ensuing operation.

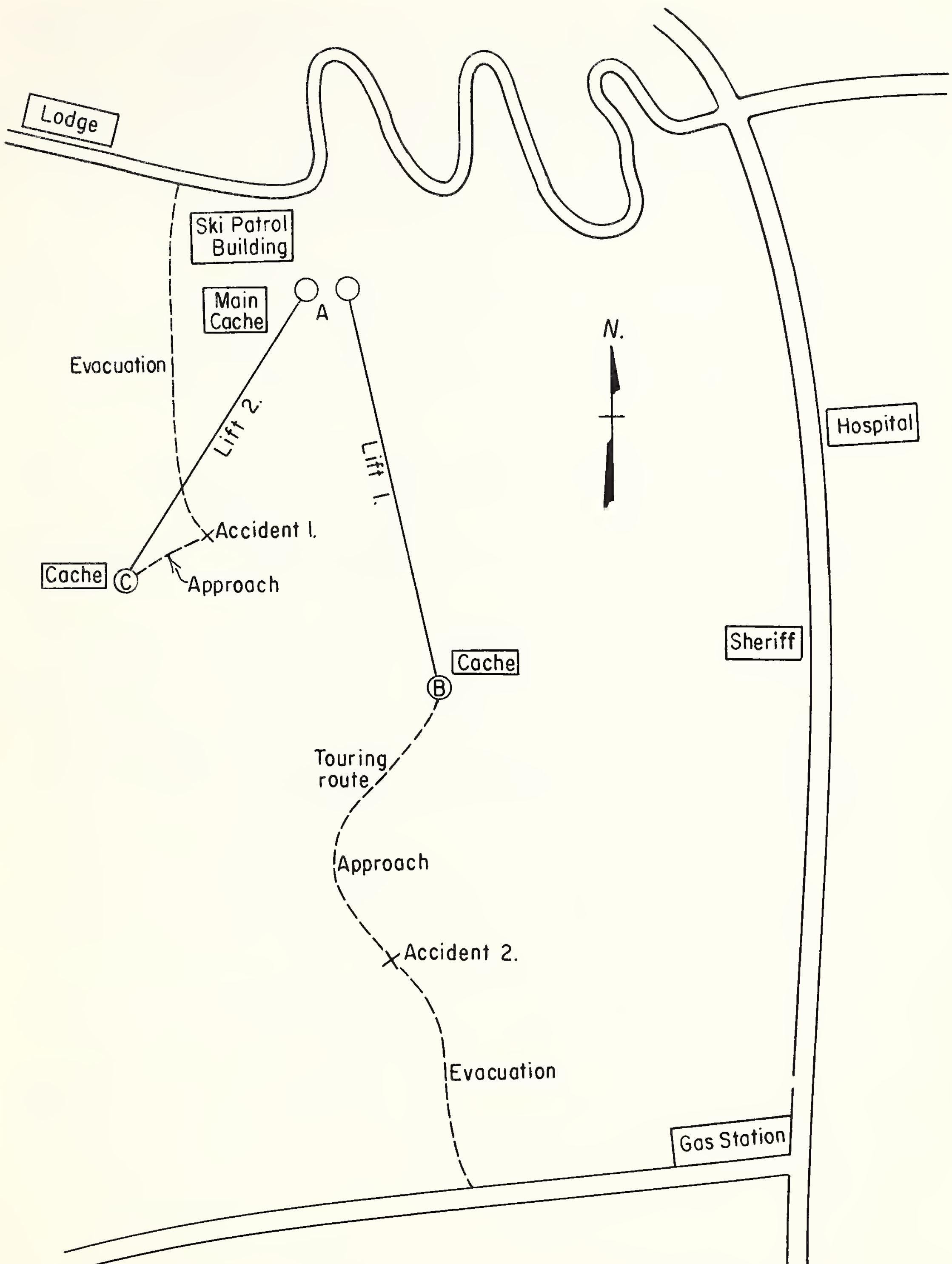


Figure 3. Two accident situations are analyzed in this fictitious ski area. "Accident 1" occurs in the lift-serviced area. "Accident 2" involves a ski touring party.

4. The rescue leader communicates to lift terminals at A directions that will move all available manpower to C. Volunteers already assembled at C are dispatched at 1510 in a first column (the hasty search column) to the accident under the leadership of a ski patrolman. They carry probes, a shovel and the resuscitation pack. Volunteers at A go up Lift No. 2 with equipment from the main avalanche cache. Manpower assembled at B are directed to ski down to A, pickup additional equipment and proceed up Lift No. 2.

5. Rescuers arriving at C depart for the accident scene in columns of 10 or less, each under direction of column leaders (designated by the rescue leader). Each rescuer carries a probe; some in addition carry rucksacks with other equipment (shovels, first-aid gear, etc.).

6. The hasty search column leader assumes temporary command of the search when he arrives on the accident scene. At the discretion of the rescue leader, either the hasty search leader or one of the subsequent column leaders is appointed accident site commander. The site commander should carry a portable radio for contact with the rescue leader. Dispatch of the First Stage is now complete.

7. Organization and dispatch of Stage II now begins. A first-aid and evacuation group is assembled. A physician is recruited from among visitors to the ski area. He is dispatched to the accident scene in a small column under leadership of an experienced ski patrolman who is also responsible for getting a toboggan to the scene. This column picks up Stage II medical supplies, tent and sleeping bags from the main cache and proceeds to the accident via Lift No. 2.

8. In the meantime the rescue leader has alerted civil authorities. An ambulance is requested with instructions to meet the evacuation party in front of the ski patrol building.

9. The victim is located by first pass of the coarse probe line at 1535 and quickly uncovered. Resuscitation begins immediately.

10. Stage II columns arrive at 1540. The physician assumes direction of first-aid measures for the victim, who has responded to the resuscitation. The victim is quickly warmed and placed in a sleeping bag and made comfortable on a toboggan. As soon as the physician approves his being moved, he is transported to the ski patrol building and the waiting ambulance (arrival at 1610).

11. In this case a well organized group carried out a rapid and efficient rescue. It was never necessary to execute Stage III.

1.5 A Back-Country Rescue

Avalanche rescue operations occurring in the vicinity of lift-served areas can be organized quickly. In the previous example, the rescue was well underway in 15 minutes. When the accident occurs in terrain which is less accessible, the organization of the rescue becomes more difficult. Refer again to Figure 3. An accident, designated Accident 2, occurs durings a ski tour by two persons (time 1500). One person is buried. The survivor skis out to the highway and hikes to the gas station. Because this is an area of widespread avalanche hazard, this gas station has been provided a copy of the written rescue plan. The gas station attendant manages to contact a designated rescue leader. The rescue proceeds:

1. The rescue leader calls lift terminals at A and the area alarm is sounded (time 1530).

2. As in the previous rescue, lift operators hold manpower at terminals A, B, and C.

3. The rescue leader contacts the sheriff's office and requests transportation of the survivor from the gas station to A.

4. The rescue leader directs transfer of standby manpower and First Stage rescue equipment to B.

5. The survivor has not been able to give a clear description of the accident site over the telephone. It is necessary for him to guide the rescue columns to the scene. While the survivor is on the way, First Stage columns are organized at B and a Second Stage medical and evacuation group is assembled, including a physician.

6. The survivor under sheriff escort arrives at A. He is quickly refreshed and transported to B.

7. First Stage columns depart from B at 1600. The survivor and the accident site commander are in the lead column. Rescuers are equipped with probes, climbing skins and avalanche cords. One shovel is carried per column. The resuscitation pack is in the lead column. The site commander maintains radio contact with the rescue leader.

8. The first-aid and evacuation group (Stage II) is dispatched from B at 1610.

9. The rescue leader alerts the hospital and ambulance service.

10. Organization of Stage III commences. The rescue leader solicits supporting manpower, food, hot beverages, illumination equipment, warm clothing, etc.

11. With the sheriff's assistance, volunteer manpower is brought in from the neighboring village. Stage III is dispatched from B at 1700 hours under the supervision of a support group leader.

12. After a prolonged search involving all three stages, the victim is located by fine-probing at 1900 hours. He is apparently lifeless, but vigorous resuscitation measures are successful in the shelter tent set up by the Second Stage group.

13. As soon as the victim is located, the site commander notifies the rescue leader by radio and he dispatches an ambulance to roadside terminal of the evacuation route.

14. The victim's critical condition requires slow evacuation with constant medical attention. He reaches the road at 2030 hours and is quickly transported by ambulance to the hospital.

15. The rescue operation is closed only after the site commander, who brings up the rear of the last columns exiting by the evacuation route, has reported to the rescue leader that all rescue parties are accounted for and have been discharged.

1.6 Touring Accidents

The overall scope of Snow Safety Guide No. 1 is limited to the emergency rescue performed by dispatched rescue groups, but a few comments on self-rescue by touring groups is also in order. When an avalanche victim is caught in the back country far from sources of help, his best chance of survival depends on his own effort to keep above the flowing snow, plus what his comrades on the scene can do to extricate him before going for help. The low probability of survival after one hour indicates how essential it is that a touring party be fully equipped for self-rescue.

Three basic safety rules can be repeated here:

1. Avoid traversing avalanche fracture zones. This is simply the application of sound principles of route-finding.

2. If danger areas must be traversed, they should be crossed by one man at a time. Only one member of the party at a time should be exposed to possible avalanche danger. If he is caught in a slide, the others can go to his rescue. If all are caught at the same time, no one may be left to perform the rescue.

3. If a victim is buried in an avalanche, the rest of the party should expend their efforts in an organized search with whatever resources they have available. Only if other help is just a few minutes away, should the rescue attempt be abandoned in favor of going for outside help. If the touring party is large, a messenger can be spared while the search proceeds. The history of avalanche accidents has too many instances of survivors departing an avalanche

accident scene in panic to seek help, when a few minutes of organized search would have uncovered the victim.

Each member of the touring party should carry a sectional probe. At least one shovel (collapsible) should be carried by the group. Skis can be used as improvised digging implements, but they are inefficient. It is hard to excavate a six foot hole in avalanche debris even with a shovel. First-aid equipment should be carried as a matter of course by any touring party. Attachments for converting a pair of skis to an emergency toboggan are also useful.

The survivors can organize a coarse probe line according to techniques described in Section 2.3, after the most likely burial spots have been probed in a hasty search. The length of time devoted to such a search will be highly variable, depending on size of the avalanche, number and condition of the survivors, and distance to outside help. The tour leader has to weigh these factors in deciding whether to continue a prolonged search or go for more help. In any case, last-seen points and locations of any surface clues should be plainly marked. If the accident site is to be abandoned while help is sought, the markers must be big enough to survive burial by snowfall.

Survivors leaving the scene to seek help must travel swiftly but prudently. It is more important to deliver a report of an accident with a few extra minutes delay than not to deliver it at all due to a broken leg or another avalanche accident. Special care must be taken to avoid avalanche slopes. The fact that an accident has already occurred warns of unstable snow.

1.7 Special Precautions

If not properly handled, the rescue operation may expose the rescuers to the same hazards which trapped the victim. The importance of speed cannot be overemphasized, but speed must be tempered with a keen regard for safety. The rescue leadership has a special responsibility to the safety of volunteers who offer their services. Five areas of the rescue operation deserve special attention:

1.7.1 Selection of Manpower

With the degree of difficulty and physical requirements of the rescue determined, it is each column leader's responsibility to screen out anyone unfit for the operation. The skiing requirements of the rescue may be formidable; if so, only expert skiers may participate. If the march to the accident scene is arduous, a single member of a column in poor physical condition may jeopardize the entire column. Mountaineering experience may be required; in this case only a limited number of volunteers may qualify. Older men with long experience in ski touring and mountaineering often make the best rescuers. Vigorous but inexperienced youths sometimes will play out in the course of an extended rescue because they have not yet learned to pace themselves and conserve energy.

Figure 4. Column leaders must screen out volunteers who are not suited for the rescue. Good physical condition, skiing ability, and mountaineering skills may be required to guarantee the success of the operation.

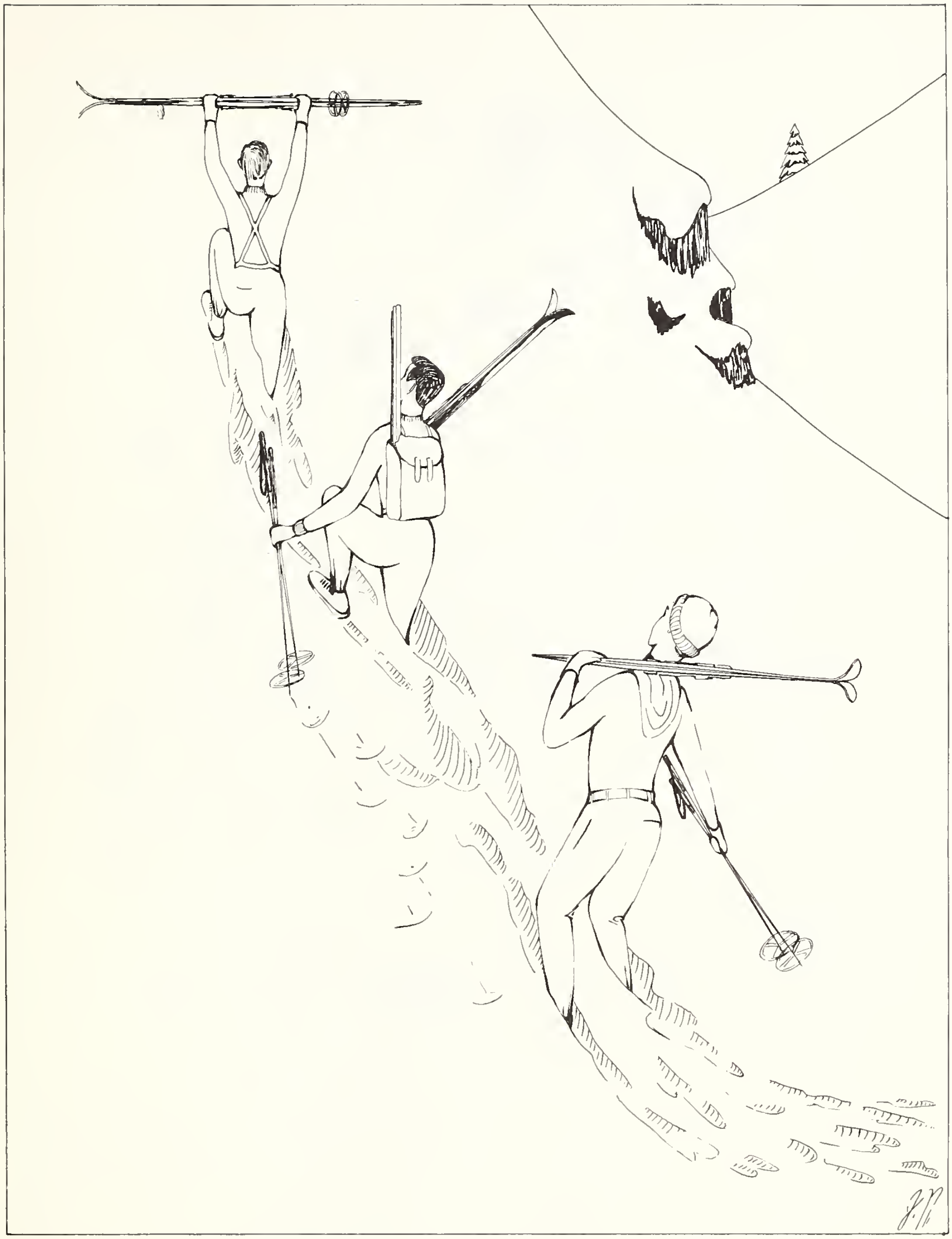


Figure 5. Volunteers are at a serious disadvantage when not properly equipped for uphill travel. Caches which are used for the dispatch of back-country rescues should contain a variety of climbing skins, snow shoes, or whatever is appropriate for negotiating the local terrain.

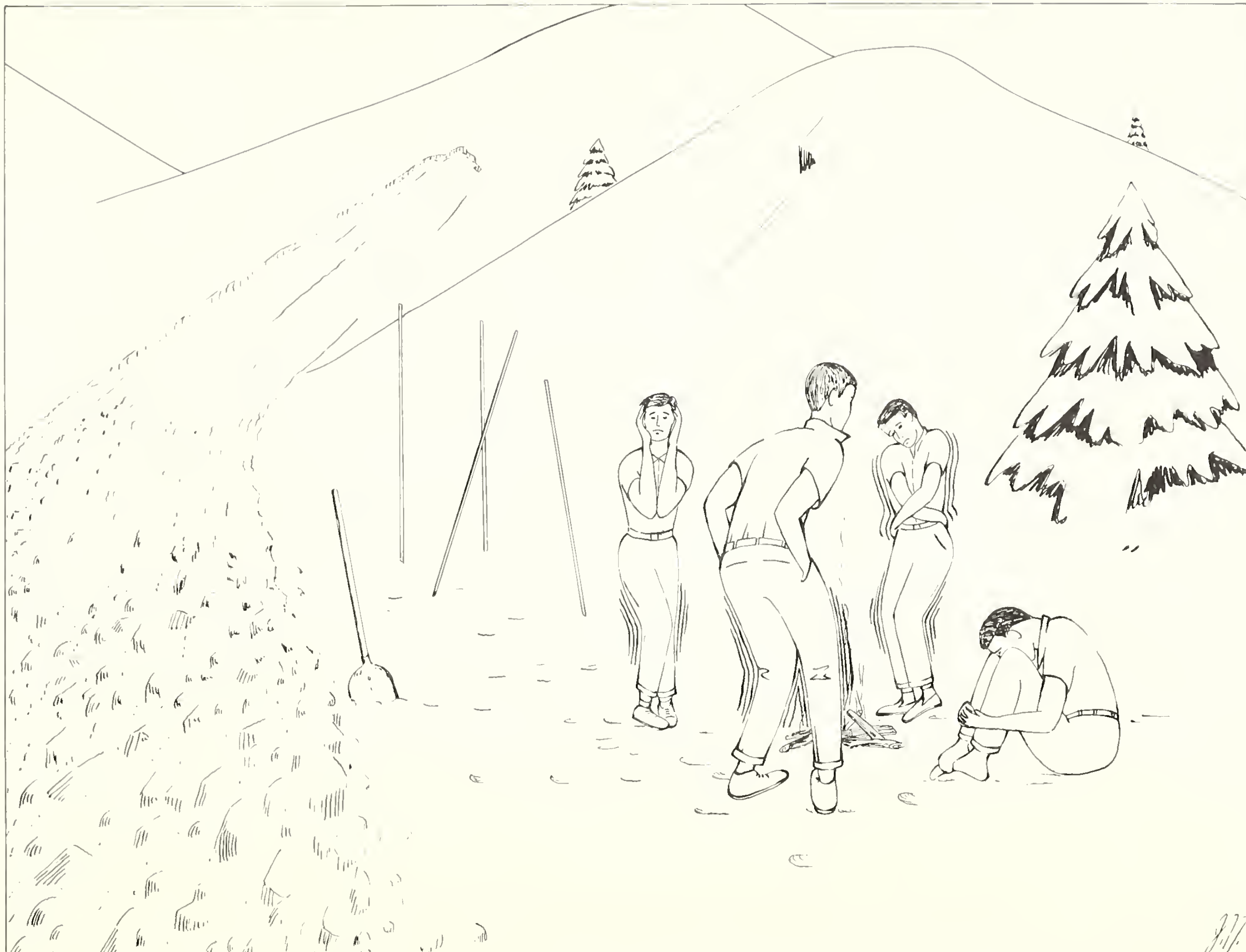


Figure 6. Volunteers must have adequate clothing for the approach, a rescue operation, and an emergency retreat if necessary.

Figure 7. The rescue leader designates the safe approach route. Each column follows this assigned route. During adverse weather conditions it may be necessary to mark the trail with wands. Column may endanger one another by avalanche release if they follow separate routes.

1.7.2 Proper Travel Equipment

Attempts to gain extensive elevation on skis by side-stepping or herring-boning are inefficient and frustrating. They may seriously slow down a party in deep, soft snow. When extended uphill travel to the accident scene is required, climbing skins are a necessity. The use of snowshoes should not be overlooked as an efficient means of breaking trail through deep snow. In fact, many rescues can be conducted more efficiently on snowshoes alone, although the dedicated skier may sometimes be reluctant to admit this. Each mode of oversnow travel has its advantages, depending on terrain, snow conditions and experience of the rescuers. The choice is up to the rescue leader.

Oversnow vehicles are widely available today. Their use may often greatly simplify transport of supplies and personnel to the accident site. But the rescue leader should assure himself that the available machines are reliable and that the accident site is indeed accessible by machine in the prevailing snow conditions before he commits his rescue columns to mechanized transport.

The speed advantages of helicopter transport to outlying accidents are so overwhelming that this means of transportation should be used whenever equipment availability and weather permit.

1.7.3 Proper Personal Equipment

Each column leader should make sure that all Stage I and Stage II volunteers have sufficient clothing for the approach march, a rescue operation, and an emergency retreat if necessary. "Sufficient clothing" for these three functions (but often insufficient for an extended rescue or bivouac) includes dry parka, mittens, wool hat and wool socks. The perspiration of a day of hard skiing may saturate a volunteer's clothing. Skiing in rain or snowfall close to the freezing point can do the same. The volunteer with wet personal gear is apt to become a liability which should be excluded by the column leader. Stage III columns should bring up clothes and equipment needed for continued warmth and efficient rescue work.

1.7.4 Safeguarding the Approach March

The rescue leader decides upon the approach route to the accident site. Each column in turn follows this route, which should be flagged by the first (hasty search) column. Rules of safe touring should be obeyed at all times. These rules include wide spacing of the party in avalanche terrain, deploying avalanche cords, avoiding avalanche release zones and belaying on dangerous traverses. This latter precaution can be especially pertinent if the rescue party has to descend an avalanche path which has just slid (possibly that involving the victim). Avalanching sometimes uncovers or creates a hard, smooth ice layer which provides dangerously slippery footing. Accident case histories indicate this is a recurring serious hazard. Climbing rope is an essential part of every rescue cache.

If avalanche slopes threaten the approach route, it may be advantageous to dispatch a blasting party to stabilize these with explosives. Stringent safety precautions are then required to avoid danger to rescue columns from artificially-triggered slides.

1.7.5 Safety During the Search

The accident site commander has the responsibility of conducting a safe search operation. He needs to keep track of all rescue personnel and see that individuals or small groups do not wander off where they become lost or involved in another avalanche accident. If avalanche danger surrounds the accident site, close control of the rescuers is essential to be sure no one gets into a release zone and triggers another slide. If additional avalanche danger threatens the search scene, an avalanche guard must be posted to warn the rescuers if another slide falls toward them. This guard must be posted in a safe location and equipped with a signaling device plainly audible and known to the rescuers. A whistle, horn or power megaphone make satisfactory signals. The rescuers working on the accident must have clear instructions about which way to run if another avalanche is signaled. (See Figure 8.)

Because avalanche victims are often trapped in gulleys, there is a very real prospect of other slides funneling into the search area. Rescue in such terrain requires extra care to protect the searchers. In the case of severe and rising avalanche hazard (during a storm, for instance), the accident site commander may be justified in calling off the search if there is too great a risk to the rescue party.

1.8 Equipment

Adequate equipment--adequate both in quality and quantity--is essential to the support of an avalanche rescue. The proper equipment depends on size and nature of the area and degree of avalanche hazard. The important factors are size and number of avalanches, degree of hazard (frequency of human encounter with avalanches), the difficulty and extent of the terrain, character of available transportation, and severity of the climate. Equipment specifications cannot be drawn to meet every conceivable requirement, but the minimum essentials can be described.

Because avalanche rescue is associated with problems of negotiating mountainous terrain, much avalanche rescue equipment is basically the same as mountain rescue equipment. Special additions are probes, shovels and auxiliary search equipment. First-aid equipment places extra emphasis on respiratory apparatus.

Recommended minimum rescue equipment is itemized here according to the operational stages. Details about sources, cost and specifications for individual equipment items are found in Appendix i.

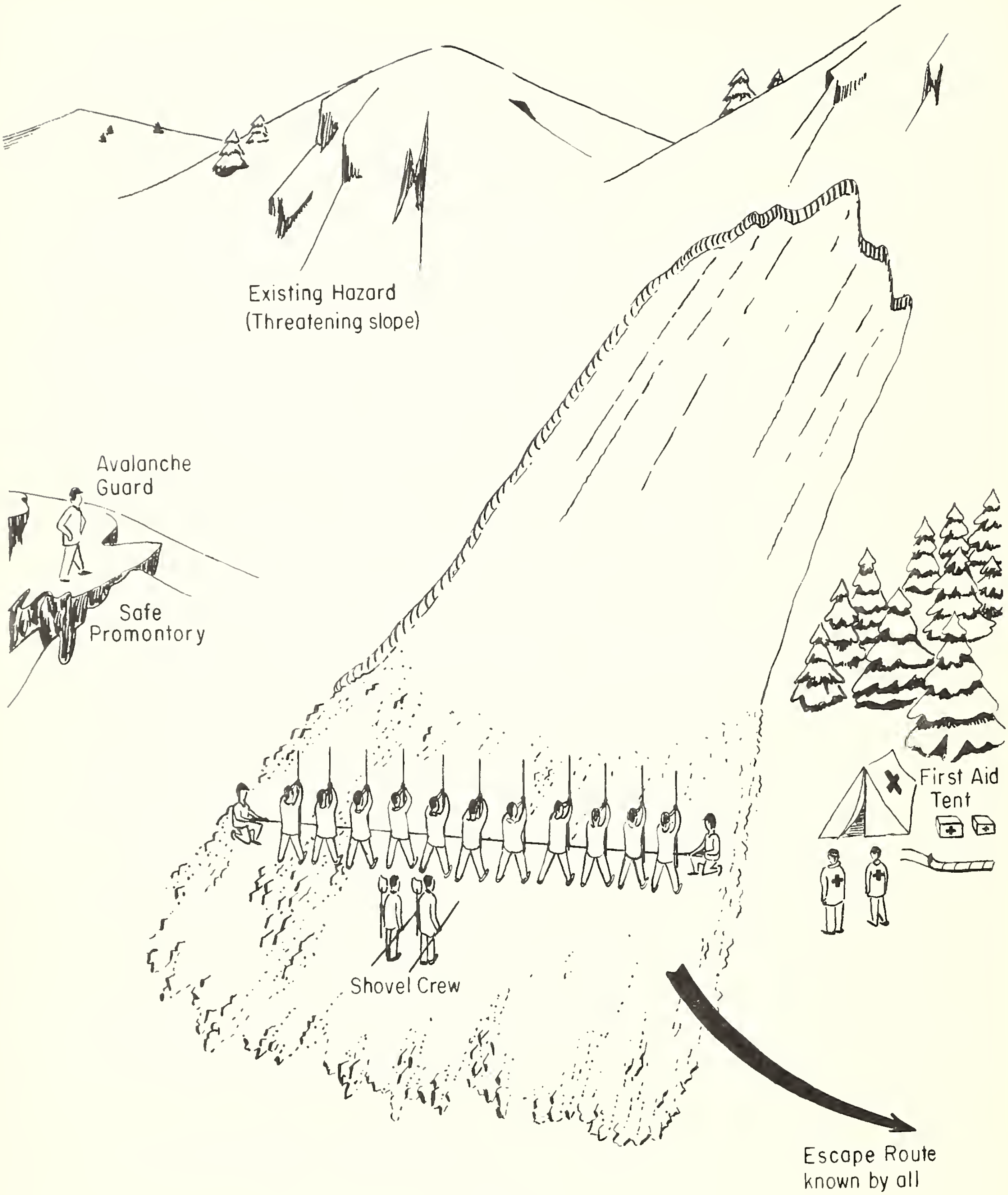


Figure 8. The search and its protection. An avalanche guard has been posted and each volunteer is acquainted with the escape route. First-aid facilities have been set up in a protected area.

Stage I

Avalanche probes

-- one-piece
-- sectional

Avalanche cords

Climbing skins for skis

Climbing rope (7/16" x 120')

First-aid pack, including resuscitator

Rolls of friction tape

Headlamps and spare batteries

Portable radio

Shovel pack containing:

-- D-handle aluminum shovel
-- Bundle of wands or flags (Trail
-- Roll of red flagging tape Markers)
-- Ball of heavy cord
-- Flares
-- Compass

An appropriate number of Stage I caches containing the above equipment can be located throughout the hazardous area. (See Figure 9.) As a guideline, Stage I caches should be no more than 15 minutes away from any hazardous area which receives continuous public use. In the hypothetical area shown in Figure 3, Stage I caches are located at B and C. The main cache at A contains equipment for all rescue stages. (See Figure 10.) This arrangement is only suggestive and reflects the economics involved in having only one main cache containing the relatively expensive medical and support equipment. During the winter months the caches must always be accessible and unlocked. This usually means location of each cache outdoors and construction of weatherproof materials. The caches should be built with compartments to separate the smaller items. One compartment is set aside for storage of the rescue plan, job description and maps. A larger section is needed for storage of the shovel packs, resuscitation pack and sectional probes. The longer, one-piece probes can be attached to the outside of the cache, but secured against irresponsible skiers borrowing them for slalom poles.

Having both sectional and one-piece probe poles gives flexibility to the First Stage columns. Because of their greater rigidity and strength, one-piece probe poles are preferred for extended rescue operations. For long approach marches, however, the one-piece probe is cumbersome. The sectional or collapsible probe is better.

In an area with moderately extensive hazard, at least 50 probes should be available. As many as possible should be in First Stage caches (15-20 in each cache is a common figure) where they will reach an accident scene in minimum time. The total number will vary with size and number of avalanche danger zones and the probable number of available rescue volunteers. The supply of probe poles should be adequate for an extended search, including an extra supply to replace promptly those bent or broken during a rescue.

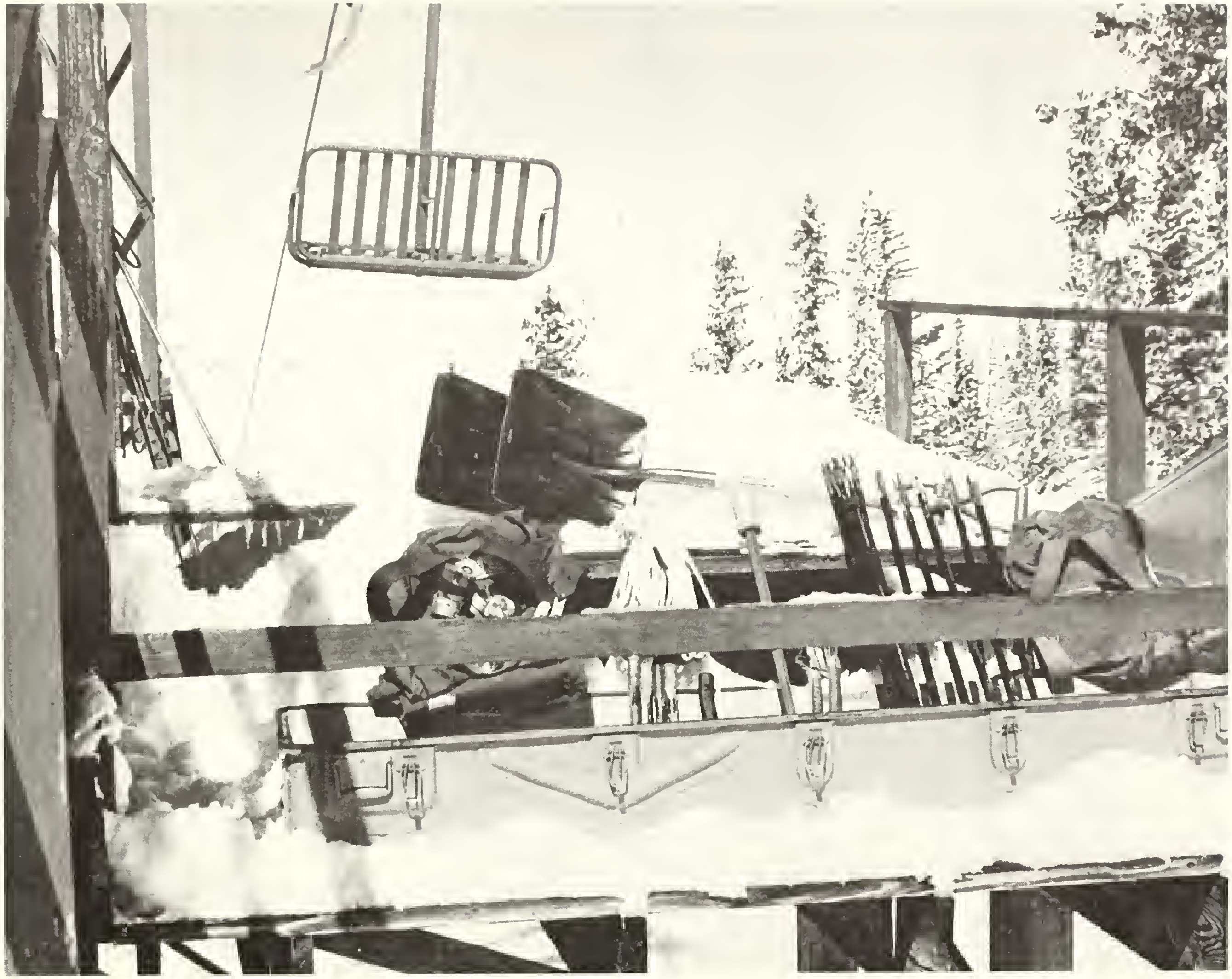


Figure 9. A First Stage rescue cache at the top terminal of a major ski area. The items shown outside of cache from left to right are: headlamps, shovels, rope, wands, sectional probes, and pack. First Stage caches must be distributed throughout the hazardous area.

Figure 10. U.S. Forest Service main avalanche cache which contains equipment for all three rescue stages.

Durability is essential to avalanche probe poles. This quality should take precedence over weight, convenience and cost economics. Any probe slender enough to be pushed easily into avalanche debris, yet sturdy enough to withstand prolonged use in dense, hard snow has to be stoutly made. Most sectional probes are poor in this respect; they are intended primarily for short search operations in relatively loose snow. The military antenna sections (MS-116A) described in Appendix i are an exception, but their cost is high. In one-piece probes, aluminum is a very poor substitute for steel. Soft aluminum electrical conduit is especially poor. Not too many years ago most avalanche caches in the United States were stocked with aluminum conduit for probe poles because this material was cheap and readily available. The number of twisted aluminum pretzels which have been abandoned at the sites of actual avalanche rescues testifies to the inadequacy of aluminum conduit. Thick-wall aluminum pipe is better, but there is no substitute for steel. Steel-tube probes now stocked at several major avalanche caches have been used time after time on rescues and for training as well, but are still in excellent condition. The correct specifications for one-piece probe poles are given in Appendix i.

Climbing skins for skis are essential if any extended march to back-country rescues involves uphill climbing. The number of skins for First Stage columns should at least match the number of sectional probes. Several lengths of skins should be stocked, along with an adequate supply of friction tape for adaptation to miscellaneous skis and for repairs.

No special pack is needed for transport of probes, skins, avalanche cords and rope. Sectional probes can be taped to ski poles for extended transport. One-piece poles should be taped together in bundles of 3 or 4 and provided at one end with a short length of rope for attachment to a belt or rucksack strap. Allowing the long probes to drag along behind frees the skier's hands to use his poles for climbing. Prepacking the shovels on light-weight packboards is desirable. These packs can also be used for transport of wands, flags, cord, flares,etc. Two or three small packs are better than one large one; a heavy pack is an unnecessary burden on a fast-moving First Stage column.

The resuscitation pack contains standard first-aid equipment for the victim, plus a resuscitator and aspirator. (See Appendix i.) Each column should also carry at least one standard ski patrol first-aid belt in case of accident to the rescuers.

Each departing rescuer should be equipped with a headlamp and spare batteries in case the operation extends beyond daylight hours. The record of avalanche rescues teaches that most of them do.

Stage II

Avalanche cords	Standard first-aid equipment
Climbing skins	Medical supplies for use by physician
Climbing rope	Portable toboggans (light-weight or sectional)
Headlamps and spare batteries	Large sleeping bags
Portable radio	First-aid tent and heater

Problems in cross-country travel are the same for all rescue stages. Sufficient avalanche cords, climbing skins, rope and headlamps must be provided for the Stage II and Stage III columns if a march into the back-country might be required. These items are less critical if likelihood of avalanche accidents is confined to areas served by ski lifts or otherwise accessible.

Stage II brings to the accident scene the necessary equipment for care and evacuation of the victims. Medical supplies are divided into two categories: (1) Items utilized by persons trained in first aid, and (2) items for use only by a physician. In general, (1) represents standard first-aid and resuscitation equipment, while (2) includes injections and medications. Care of the recovered avalanche victim is discussed in detail in Section 3.

For lift-served area, standard ski patrol toboggans are satisfactory. For back-country rescues, light-weight or sectional toboggans such as the Akja are necessary. Sectional types which can be broken down and mounted on packboards are much preferred. They should be so mounted and kept ready to go in the avalanche cache (see Figure 11). Large sleeping bags with full-length zippers are essential for warming and handling the victims. Down-filled bags are the best, for they are light and compact to transport as well as offering maximum insulation.

The various supplies for a Stage II column should be kept packed in rucksacks or packboards ready for transport. Packs weighing 20 to 30 pounds will usually be the most convenient. A normal full compliment of Stage II equipment will require five or six men for transport. If the route is long and arduous, provision of a relief column to share the packing chores will speed travel.

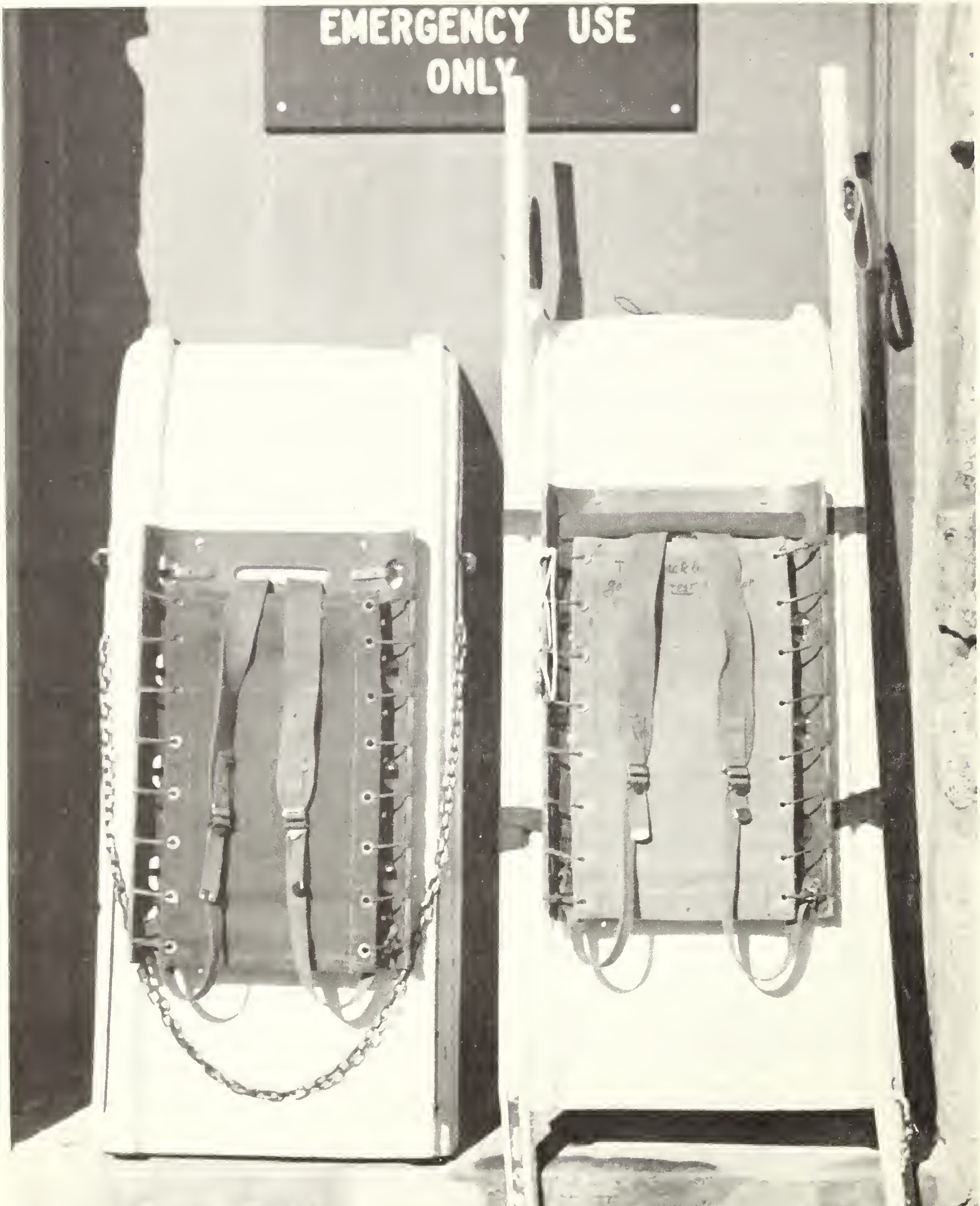


Figure 11. Sectional toboggans, mounted on pack frames, can be carried to the accident site in the Second Stage.

Stage III

As Needed:

Avalanche cords	Probes	Gas Lanterns
	Shovels	Heavy illumination equipment
Climbing skins	Tents	
	Stoves	Food
Climbing rope	Flares	Hot Beverages
	Blankets	Sleeping bags
Headlamps and spare batteries	Warm Clothing	
	Snowshoes	
Portable radio		

Stage III provides the backup support for a prolonged rescue. In addition to the regular equipment needed by each member of the column (left-above), the main requirements are for food, warmth and relief manpower delivered to the accident scene. The quantity and complexity of this logistic support depends on so many factors of terrain, climate, character of the accident and number of rescuers involved that no details can be specified here. In general, support equipment for a prolonged rescue will not be stored in avalanche caches, but can be procured from such groups as mountain rescue organizations, the Forest Service, the county sheriff or the Red Cross who are equipped to furnish major assistance. Two exceptions which should be stored or held available in advance are communication and illumination equipment.

It is difficult to conceive of a smooth running rescue operation today without portable communication equipment. A wide variety of high-quality two-way radio equipment is available in remarkably compact form. In some instances larger organizations such as the professional ski patrols at major areas may have their own equipment. More often arrangements can be made for emergency use of existing radio communications of the Forest Service, the county sheriff, or highway patrolmen and maintenance crews. most important is to have top grade equipment which is kept in good working order. Portable radios preferably should be available one for each rescue stage.

Portable power megaphones are a useful adjunct to communication. They make the accident site commander's job much easier, and can also be used to good effect for warnings from the avalanche guard. High-quality equipment is essential; the experience with inexpensive units during the rigors of a mountain storm has been poor. Megaphones using rechargeable nickle-cadmium batteries are the best, for these are much less affected by low temperatures than are dry batteries. Ideally a megaphone should accompany one of the First Stage columns. If this is not possible, access to a megaphone could at least be arranged for Stage III.

Most serious rescue operations run into the night. Personal headlamps are essential for travel and work by individual rescuers, but these provide only

the bare minimum of illumination. Organized search and probing at the accident is far easier to execute with area illumination. Only the accident site commander who has tried to direct a search by headlamps alone can fully appreciate the value of floodlights. Handy, inexpensive and portable light sources can be stocked in the form of gasoline lanterns with extra mantles, fuel and a supply of kitchen matches in a waterproof container. Large, propane-fired floodlights are available which provide ample light for a major search operation, but their bulk and weight verge on the inconvenience for backpack transport. Such floodlights may be profitably stocked in main caches if mechanical transport is apt to be available. In large, lift-served ski areas where most prospective accident sites can be reached by downhill travel from a lift terminal, an illumination package can be assembled for quick loading on a ski patrol toboggan. This consists of a small, portable gasoline generator, an electric floodlamp, a supply of fuel, and spare lamps.

2. METHODS OF LOCATING AVALANCHE VICTIMS

The concept of probability is important to the design of search operations. The object is to optimize the victim's chance for survival. Decisions are required which increase the probability of finding the victim alive. There is a double requirement for success: The victim must be found, the victim must be found alive. Clearly, a slow and thorough search could be organized which would almost guarantee finding the victim, but the chances of finding him still alive would be slim. The following sections will explore techniques which increase the probability of finding a victim alive.

2.1 General Procedures

The precautions of Section 1.7 are assumed. These are the guidelines at the scene of the accident:

1. Either from witnesses or by examination of clues, establish where the victim was located just prior to the avalanche release.

2. Determine the point where the victim disappeared--the "last-seen" point.

3. Making use of the above and any other available information, establish a probable victim trajectory in the avalanche leading to search regions of high priority.

4. Make a rapid but systematic check of the avalanche debris surface. Mark all clues.

5. If justified, make initial coarse probes of high-priority regions. The justification for initial probes of certain high-priority regions will be given in Sections 2.2 and 2.4. The coarse probe is explained in Section 2.3.

6. Make a coarse probe of all likely areas of burial.

7. Repeat the coarse probe as long as a live rescue remains possible.

8. Resort to the fine probe only when the probability of a live rescue has become slight.

The precise way these guidelines are applied will depend on the number of missing victims, size of the rescue party and nature of the search area. With enough rescuers, Steps 4, 5 and 6 can be conducted simultaneously. Steps 4 and 5 are the normal procedures of the hasty search.

Decisions concerning the search procedures are in the hands of the accident site commander. He decides when and how to search a particular region. Confronted with a multitude of variables, he has to make proper decisions quickly. In addition he has the job of operating the rescue rigorously and efficiently without sacrificing morale of the volunteers. The site

commander should have the abilities, sharpened by experience, to steer the rescue operation towards its greatest probability of success.

2.2 Establishing the Victim's Most Probable Location

In many respects a moving avalanche resembles a fluid. A human body, with a higher density than the flowing snow, would be expected to sink deeper and deeper into the avalanche. Many complex factors obscure this simple model. Turbulence, the influence of terrain, and the victim's own efforts all interact to determine the final burial position. These same factors can also increase the victim's lateral motion and make more uncertain his final position.

Although there are possible mechanisms to deposit an avalanche victim in unlikely spots, the study of a large number of case histories leads to the following generalities:

1. The majority of buried victims are carried to the place of greatest deposition--usually the toe of the slide.

2. If two points of the victim's trajectory can be established (see Section 2.1), a high probability exists that the victim will be near the downhill flow line passing through these two points. See Figure 12.

3. Any terrain features which catch and hold avalanche snow are also apt to catch a victim (Figure 13).

4. If an avalanche follows a wandering gulley, all bends which show deposition are likely burial points (Figure 14). The likelihood of a victim being buried at a particular gulley bend is proportional to the amount of avalanche debris deposited there.

5. Vegetation, rocks and other obstacles act as snares. The victim tends to be retained above the obstacle. Obstacles in the avalanche path may also simply delay the victim's motion, leading to final burial somewhere downstream from the obstacle.

6. Maximum speed of the flowing snow occurs at the avalanche center. Friction reduces flow velocity along the edges. The closer the victim's trajectory is to the center of the slide, the greater may be his expected burial depth.

7. Efforts of the victim to extricate by vigorous motion and "swimming" definitely minimize burial depth. Conversely, the limp body of an unconscious victim is apt to be buried deep.

An occasional exception to the above rules is emphasized: The victim may not be buried. In a wild Colorado slide, a fortunate survivor was hurled 10 feet in the air by wind blast and thrown to safety. There are sadder examples of victims that are thrown from avalanches or somehow manage to

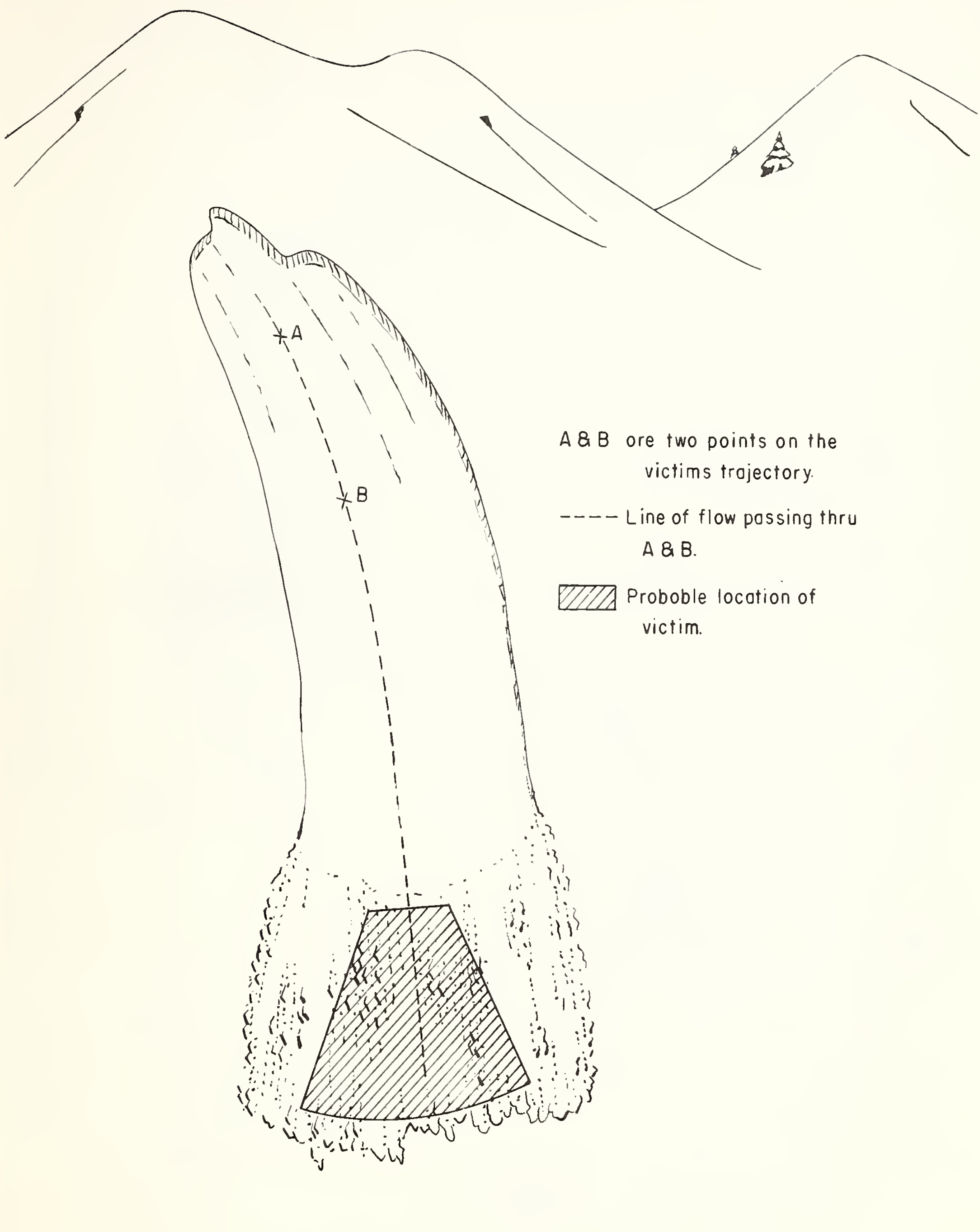


Figure 12. If two points of the victim's trajectory can be established, a high probability exists that the victim will be near the downhill flow line passing through these two points.

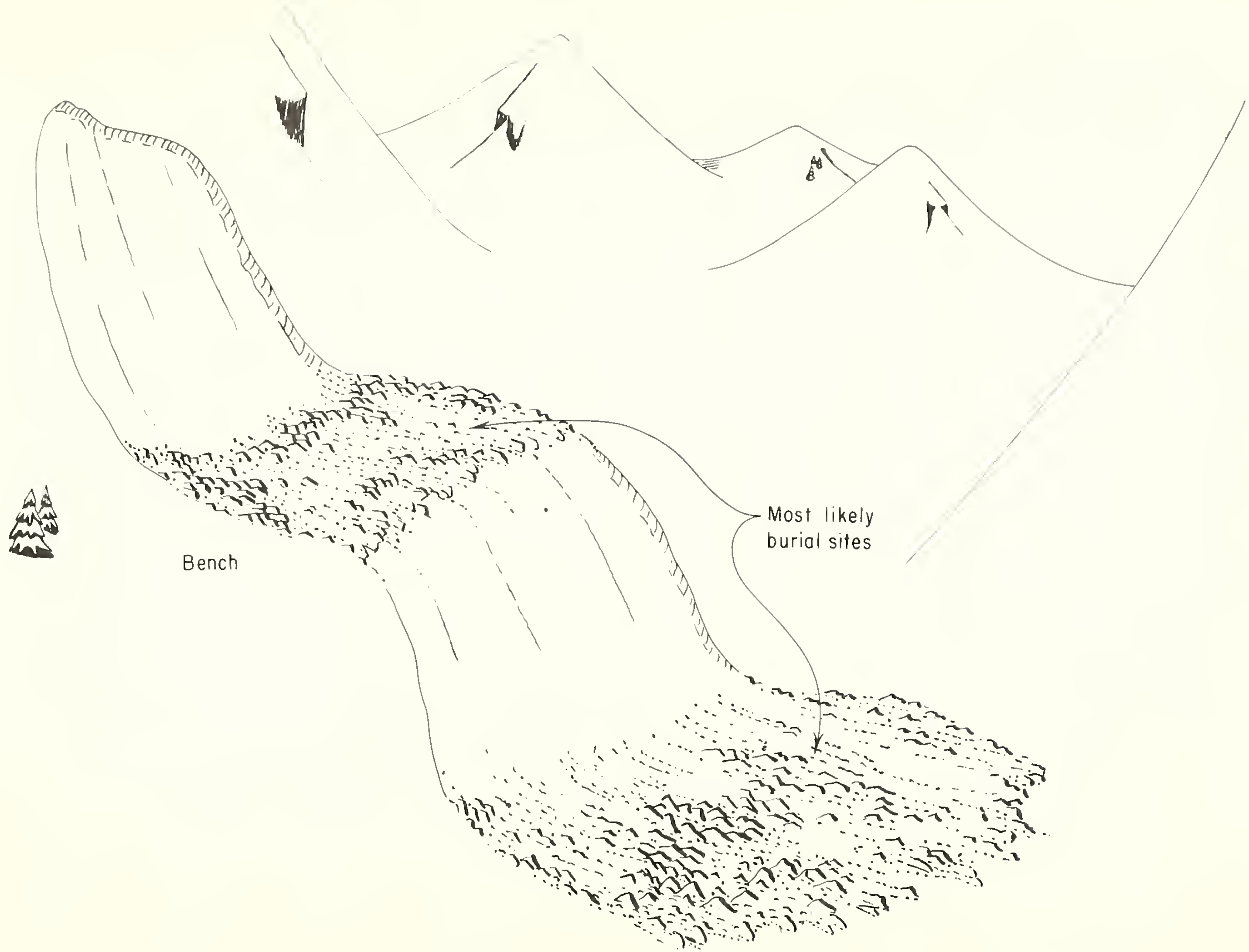


Figure 13. Any terrain features which catch and hold avalanche debris are also apt to catch a victim.

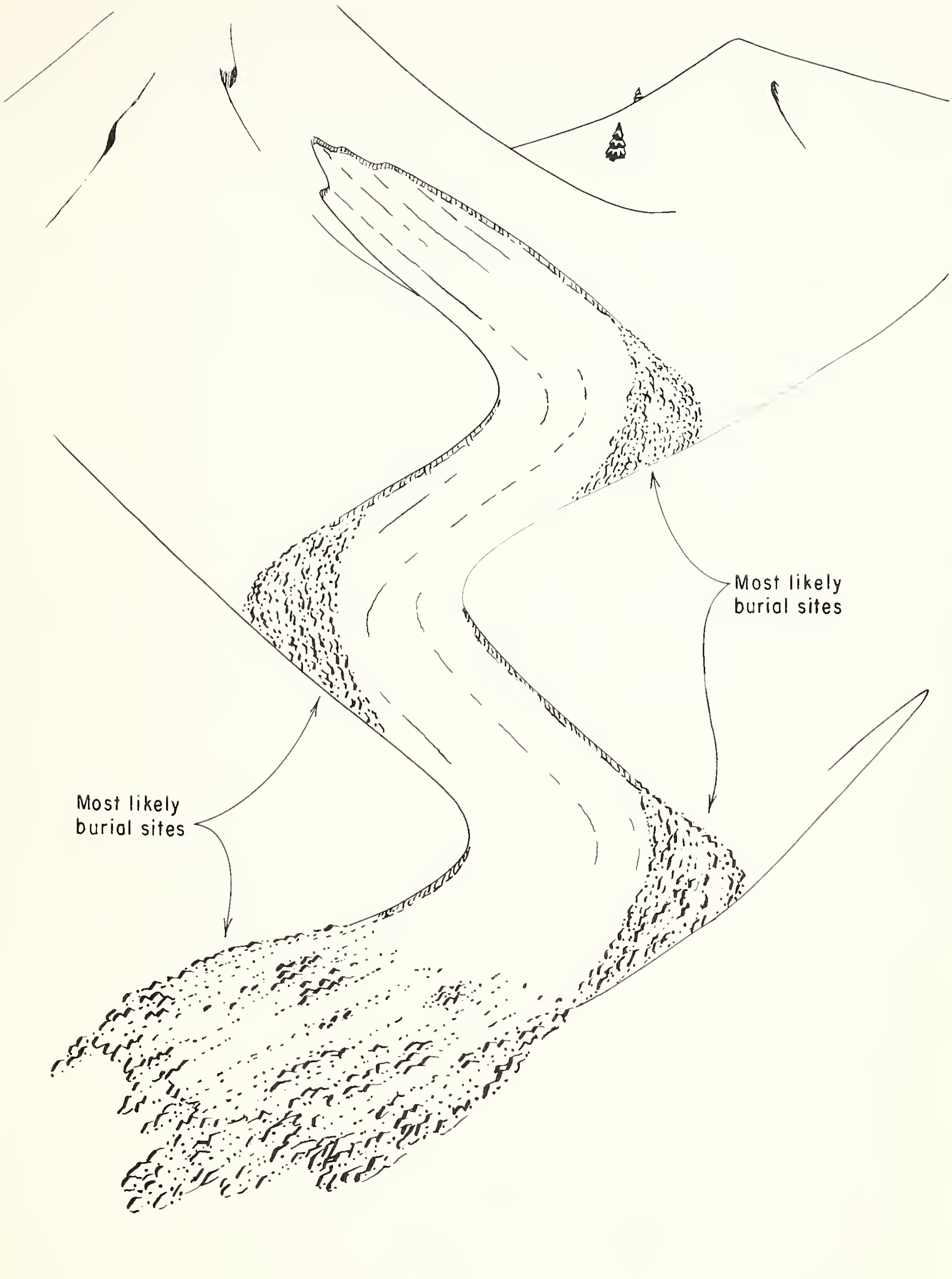


Figure 14. If an avalanche follows a wandering gulley, all bends which show deposition are likely burial points.

free themselves, only to die of shock, injury or exposure. There is one case on record of a dead victim being found in a tree after extended search of the avalanche debris. Force of the slide had hurtled his body there. In the case of large and violent avalanches, search of the surrounding terrain is advisable.

2.3 Coarse and Fine Probing

The popularity of probing for an avalanche victim stems from this method's simplicity. In the technical scheme of search methods, the victim can be located by probe poles because his mechanical permeability differs from that of snow. (This difference may be small in hard, dense snow; more than one dead avalanche victim has been recovered with his body pierced by probe poles.) Probing offers the advantage of requiring very simple equipment that can be operated by volunteers without previous training.

While the probers do not need previous training (although some practice helps), the search leader must be familiar with the technique to insure proper execution of search by probe line. The following general guidelines for probing are suggested:

1. Rigid steel tubing, 3/8 to 1/2 inch in diameter, is recommended for probe poles (see Appendix i). Lengths of 10 to 13 feet are most convenient. Longer poles are difficult to manage, especially in a high wind. Standardizing the length of poles at a given rescue is an advantage. When the probe poles are of equal length, it is obvious when one probe in a line is stopped short by an obstacle.

2. Among those who have actually located a victim by probing there is a consensus that striking a body gives a distinct feel to the probe. This feel is easily recognizable in soft snow; it is less so in hard, dense snow. Some difficulty may be encountered when probing avalanche debris which lies over spongy vegetation or muddy topsoil. Here the feel of the terrain may seem similar to that of the human body. A more common problem is encountering debris within the avalanche snow which can be mistaken for the victim. The only sure check is digging.

3. Precautions should be taken to prevent icing of the probes when large temperature variations are present. Probe poles should be kept moving in and out of the snow. Gloves which insulate probe from the prober's hands will help keep body heat where it belongs. There is some advantage in waxing the probes, although wax will be worn off by prolonged use. Probes should not be left fully inserted in the snow for long periods. They invariably will freeze in and be hard to extract. (Caution during rest breaks.)

4. For the probing operation to be effective, lines must be ordered and properly spaced. To insure systematic and orderly probing, the number of volunteers per line should be limited. Twenty per line is satisfactory; thirty an upper limit. A stringline (see Figure 8) is essential for keeping both coarse- and fine-probe lines aligned. If rescue manpower is scarce, the stringline may be omitted for the coarse probe.

5. The probe line maintains a steady advance upslope. Advancing in the uphill direction automatically helps set the proper pace and permits easy probing to full length of the poles. Downhill probing is more difficult to control. Probing does not come to a halt when a possible strike is made. The probe is left in contact with the possible strike while the probe line proceeds as before. A shovel crew follows up the strike by digging down along the probe pole which made the strike. The shovel crew should carry extra probe poles to replace those left behind at strikes. Such a scheme of operation is especially important when more than one victim is buried.

Two distinct probing techniques are recognized: The coarse probe and the fine probe. As evident in the nomenclature, coarse probing implies a wider spacing of probe pole insertions with emphasis on speed. Fine probing involves close-spaced probing with emphasis on thoroughness.

Coarse probing is used during initial phases of the search when live recovery is anticipated. Fine probing is the concluding measure which almost guarantees finding the victim. Section 2.4 will justify initial use of the coarse probe technique.

The coarse probe functions as follows:

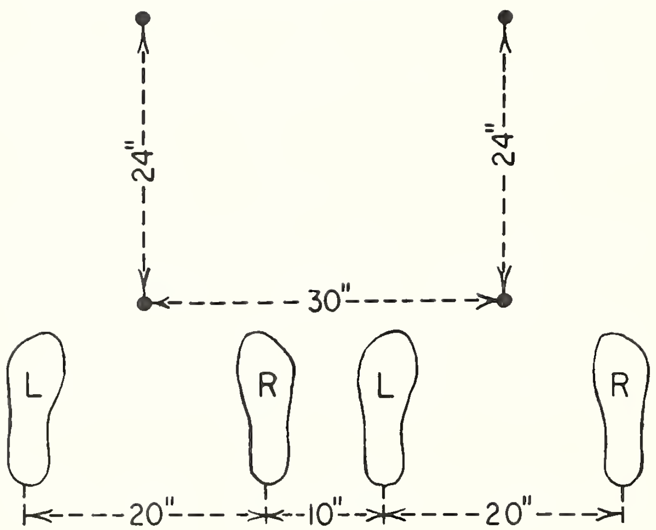
1. Probers are spaced along a line, 30 inches center to center. A distance of 20" is straddled, leaving 10 inches between toes of adjacent probers. (See Figure 15.)

2. A single probe pole insertion is made at the center of the straddled span.

3. On signal from the probe line leader, the group advances 2 feet and repeats Steps 1 and 2.

4. Usually one signal suffices for the complete sequence--insertion of probe, retraction of probe, and advancement of line. It is important that the signals be adjusted to a rhythm which enforces the maximum reasonable pace.

5. Strict military discipline and firm, clear commands are essential for efficient probing. The probers should work silently.



Execution of the coarse probe.

Figure 15. The coarse probe is used whenever live rescue is expected. The above spacing can be achieved by dressing the line "elbow to elbow" in "hands on hips" position. One probe insertion is made and the line advances two feet.

The fine probe functions as follows:

1. The volunteers are arranged the same as for the coarse probe, with 30-inch spacing center to center.

2. Each volunteer probes in front of his left foot, then in the center of his straddled position, and finally in front of his right foot. (See Figure 16.)

3. On signal, the line advances one foot and repeats the three probes.

4. The exact number of signals from the probe line leader is arbitrary, but the fine probe usually functions best when each probe pole insertion and retraction is performed on command.

5. Good discipline and coordinated probing is even more necessary than with the coarse probe. Careless or irregular probing can negate the advantages of fine probing. Use of the stringline for a guide is especially important with the fine probe. The three insertions are made along the line of the guide string, which is then moved ahead one foot to pace the probe line.

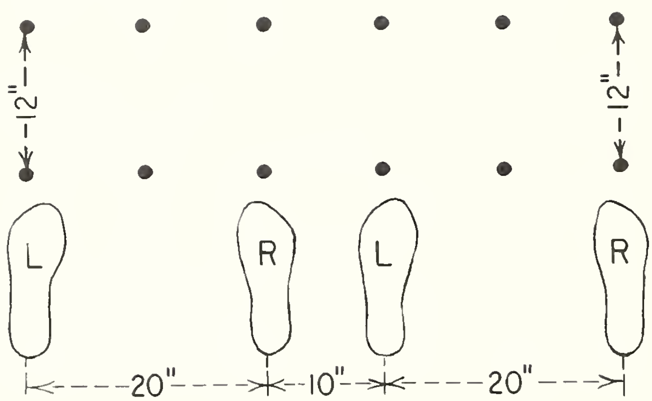
Effectiveness of the coarse and fine probes can be compared by examining the relation of sampling (probe insertion) intervals to the projected area of a human body. The result is that the coarse probe technique has a 76% chance of locating a victim on a given pass, while the fine probe has essentially a 100% chance of locating the victim.

2.4 Optimizing the Victim's Chances of Survival

If the coarse probe gives only a 76% chance of finding the victim compared with 100% for the fine probe, why is it preferred as the initial search measure? Basic probability theory provides the answer.

As mentioned earlier, the successful rescue operation is the one which gives the greatest probability of finding the victim alive. The coarse probe is not completely thorough, but it is fast. In fact, experience shows it is four to five times faster than the fine probe. A glance at Figure 1 shows the dependence of the victim's life on a speedy rescue. When gain of speed is weighed against loss of completeness, calculations show that the victim's chances of survival are greatly improved if the search operation begins with a coarse probe. (Reference No. 8.)

Suppose the initial coarse probe is unsuccessful. Should the coarse probe be repeated, or should the next step be a fine probe? This question is analogous to the coin-tossing problem: A coin has been tossed and it turns up "heads," which it has a 50% chance of doing. What is the probability it will turn up heads on the next toss? The answer is still 50%, demonstrating the well-known principle that "the laws of chance have no memory."



Execution of the fine probe.

Figure 16. The fine probe is used when live rescue is not anticipated. The set-up is the same as in the coarse probe. Three probe insertions are made and the line advances one foot.

The same logic applies to probing for an avalanche victim. If the initial use of the coarse probe gives the highest probability of finding the victim alive, then the coarse probe should be repeated over and over again until the victim is found.

If repeated use of the coarse probe fails to locate the victim after a time interval which leaves him a very slight chance of survival, the situation is altered. The probability of live recovery has now been replaced by a very strong probability that the victim is dead. Fine probing is then in order as a measure to locate the victim. His survival chances are still not zero, of course--a few victims have lived for many hours under avalanche snow. The accident site commander has to make a decision at some point in the rescue to switch to fine probing if the coarse probing is repeatedly unsuccessful. Just when this should be done will be governed by many such factors as the size of the avalanche, time since the victim's burial, number and conditions of the rescuers and the prevailing weather and avalanche hazard. The man on the scene has to make the ultimate decision.

Table I casts some light on the site commander's dilemma. It shows the increased probability of live rescue with repetition of the coarse probe. The increases are significant for smaller avalanches. They are less significant for larger avalanches and the site commander may then be justified in resorting early to the fine probe. (Reference No. 8.)

What is the optimum depth for probing? Should depth be decreased to increase speed? The answers are determined by three complex factors:

1. The probable burial depth of the victim as indicated by available clues. In Section 2.2 guidelines were given for establishing possible burial depth. Unfortunately, the overall accident picture is often unclear. The victim then is assigned equal chances of being buried at any depth up to the maximum thickness of deposited avalanche debris.

2. The probability at various burial depths of the victim being alive. This factor is dependent on the density of the snow. Under wet, dense spring snow, the victim suffocates quickly even at shallow depths. The less dense and colder the snow, the better will be his chances for survival at all depths. In general, for all types of snow, the dependence of survival time on burial depth is given in Figure 17.

3. The speed of probing to various possible depths. Steepness of the terrain and hardness of the snow both influence the rate of probing to a fixed depth. Obviously, the shallower the probing depth the more rapid the probing rate.

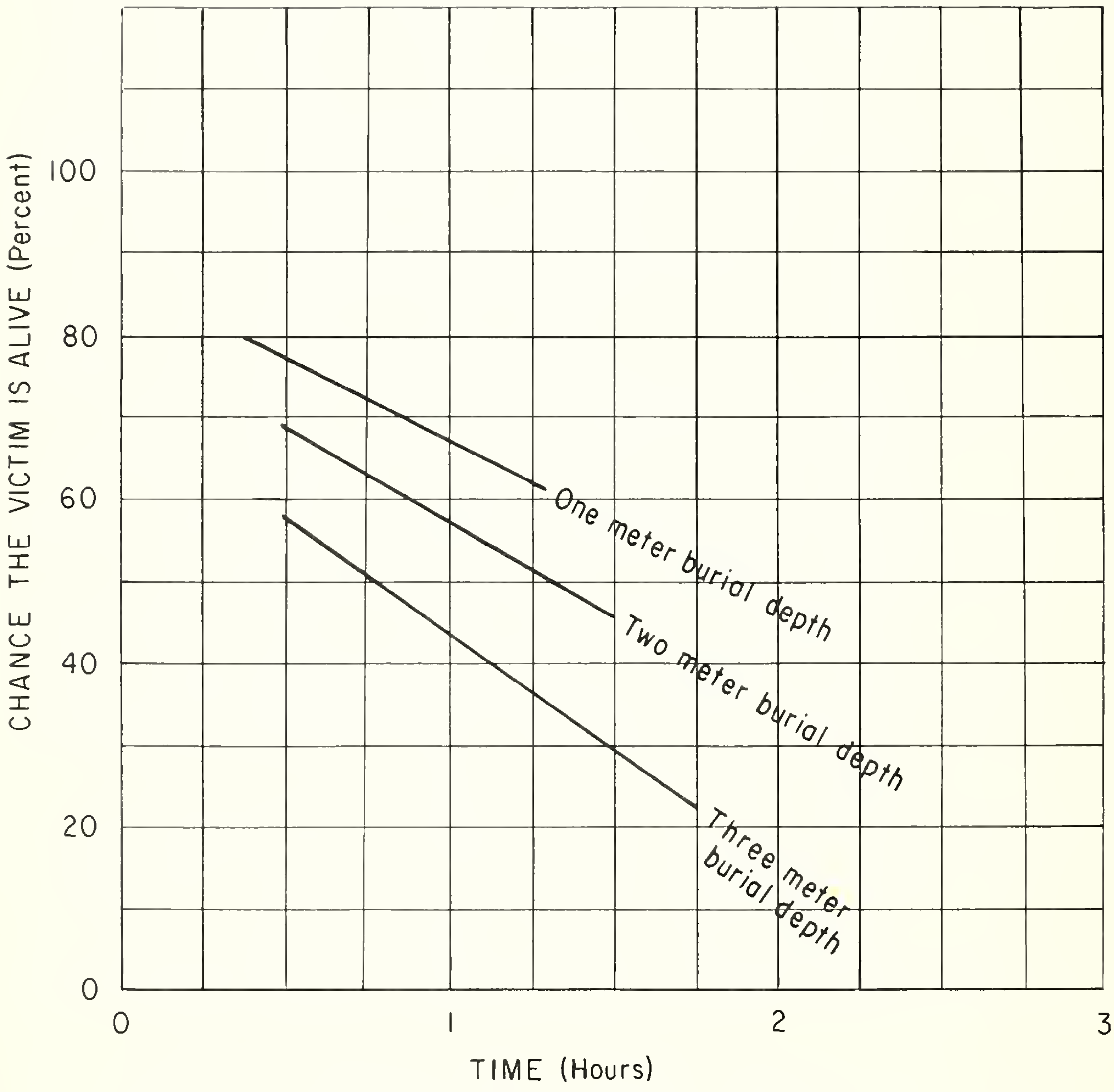


Figure 17. The chance that the victim is alive is shown as a function of time for three burial depths.

TABLE I

A. Small avalanches (coarse probe time about 15 minutes for single pass).

Number of coarse probes before making fine probe	Relative chance of finding the victim alive
0	18%
1	31%
2	39%
3	45%
4	49%

B. Larger avalanches (coarse probe time about one hour for single pass).

Number of coarse probes before making fine probe	Relative chance of finding the victim alive
0	8%
1	18%
2	20%
3	21%
4	21%

Comparison of increased speed resulting from decreased probing depth with the reduced probability of finding the victim when less volume is searched gives the following guideline: The probing depth should not be reduced to less than 10 feet in the interest of speed, except when strong evidence indicates a shallower burial depth. Strongest of the latter evidence is shallow deposition of avalanche debris recognizable by presence of ground or undisturbed snow underneath.

Finally, consider the question raised in Section 2.1. What is the basis for justifying initial probes in regions of presumed high priority (most likely burial sites)? The answer, again from mathematical analysis (Reference No. 8), confirms intuition. An initial search of a region is justified if the percent of search time required for the region is less than the probability of finding the victim in the region. For example, consider the hypothetical accident which is diagrammed in Figure 18. Which region should be searched first: The stand of firs, the bend, or the final deposition area? Ideally, a table of "relative search time" versus "probability of location" should be constructed (see Table II). The final deposition area is chosen for the first search area since the probability of locating the victim in this region exceeds the relative time required to search the region.

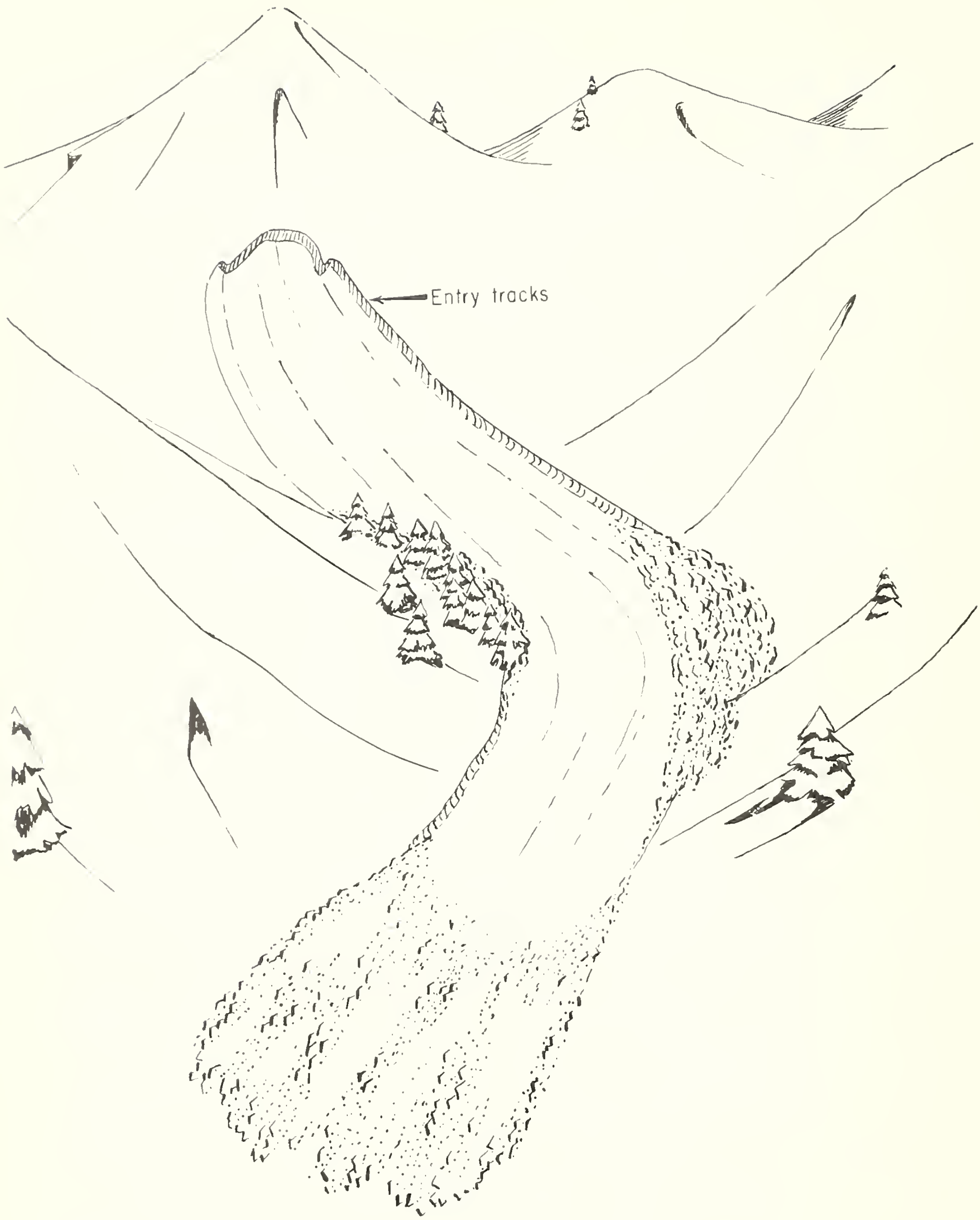


Figure 18. First Stage columns arrive at the hypothetical accident diagrammed above. A quick search of the surface fails to uncover any additional clues. Which area should be coarse-probed first?

TABLE II

Likely Point of Location	Estimated Search Time	Relative Search Time	Probability of Location
Stand of Firs	1/2 hour	25%	20%
Bend	1/2 hour	25%	20%
Final Deposition	1 hour	50%	60%

In practice the site commander is not apt to indulge in mathematical analysis during the coarse of an actual rescue. Probability of the victim's location is a subjective estimate at best, and the first guesses about required search time may be little better. But prior consideration of these probability relations can help him to gain confidence in the intuitive benefits of long experience with avalanche behavior.

2.5 The Avalanche Dog

Despite all attempts to optimize the process, probing remains a relatively slow method of recovery. Alternatives must be found. In Europe, the most workable innovation is the use of dogs which are able to detect the scent of buried victims. According to Swiss statistics, the "Lawinenhund"--avalanche dog--is very effective. In the period 1945 to 1962, dogs participated in 170 rescues. Of these, 20 were live rescues, 120 were dead rescues, and in 30 cases the dogs failed to locate the victims. The large number of dead rescues of course is no reflection on the ability of the dogs. Rather, it is another indication of the hazard of being caught in an avalanche. Only 19% of all persons completely buried in an avalanche survive, no matter what means are used to locate them.

Avalanche dogs are used extensively throughout the Alps. The system is most highly organized in Switzerland, where call to a central telephone number similar to that for police or fire will bring the nearest avalanche dog to the scene of the accident. Dogs and trainers are periodically tested and classified according to degree of proficiency and experience.

With the present growth in North American winter recreation and its concomitant avalanche hazard, a similar system would be desirable in the United States. Sporadic interest has been generated for avalanche dog training, but no organization has yet been established to provide trained dogs with the levels of proficiency found in the best European animals.

Training the avalanche dog is a continuing task. Search training must be pursued both summer and winter to keep the dog at the peak of his efficiency. The dog must be thoroughly accustomed to working in snow and winter weather. To be really useful as a rescue tool, he must be kept where he can be brought quickly to avalanche accident sites.

Figure 19. The Rescue Beacon is a small transmitter-receiver set which can be carried by avalanche control teams. In the event of an avalanche accident, buried victims would be located quickly by following the audio-induction signals emitted from their transmitters.

The avalanche dog receives a normal amount of obedience training. Contrary to the training of a police dog, he is given only pleasurable experiences with people. Master-dog relationships are built around love and comradeship. Such dogs are not subjected to the same nervous strain as "seeing-eye" dogs, but the strenuous physical requirement for avalanche work may reduce the dog's life span.

Anyone who enjoys working with dogs, lives in the mountains, and is willing to devote extra time to a serious but rewarding hobby, may become an avalanche dog leader. The prerequisites for an avalanche dog are:

1. Well-developed sense of smell and keen senses in general.

2. Large, strong, spirited and with good endurance.

3. Weather-resistant coat.

4. Easy to train and manage.

In Europe, the German Shepherd, a breed known for its intelligence and loyalty to human beings, was the natural choice. It has proved equal to the task. Certain other breeds, such as Golden and Laborador Retrievers, also meet these requirements, but to date have not been introduced as avalanche dogs.

The following conditions limit the effectiveness of avalanche dogs:

1. Scent contamination of the area before arrival of the dog.

2. Deep burial of the victim or very dense snow:

    a. Limitation of approximately 3 feet for dead victims in dense and wet snow.

    b. Limitation of roughly 6 feet for dead victims in light and dry snow.

    c. Similar limitation for deep burial of live victims, but in favorable conditions dogs have located live victims under 16 feet of snow.

3. Prolonged burial time before arrival of dog.

4. Storm and foehn (warm) winds.

5. Difficult and exhausting march to accident site.

Dogs are most effective in locating live victims buried at shallow depths in light, dry snow. Calm weather with temperature slightly below freezing is optimum.

The speed with which a trained and experienced dog can locate a buried victim has to be seen to be appreciated. Even with unfavorable conditions and in the presence of extraneous scents, a good dog will often pick up a victim's scent as much as 100 feet away from the burial point. A skilled dog-trainer team can locate in minutes a victim whom rescuers might take hours to find by probing. A TRAINED AVALANCHE DOG IS BY FAR THE BEST WAY AVAILABLE TODAY TO LOCATE AN AVALANCHE VICTIM.

Reference No. 2 in the Bibliography gives details about training avalanche dogs.

2.6 Detection Schemes for Locating Avalanche Victims

The avalanche dog is the best available search instrument today, but modern technology is also being explored for newer and better means of locating avalanche victims. The dog is inconvenient from the standpoint of time and cost of training, maintenance, transportation and endurance. A small, portable device which could be stocked in avalanche caches, be easily transported, and which would work indefinitely at the search would have many advantages. The requirements for a satisfactory search device are severe. Numerous suggestions have been advanced from time to time, but up to now no fully satisfactory device has been produced. In order to fulfill all requirements, an ideal avalanche search device must:

1. Have a fast speed of operation (search at least 400 square feet per minute).

2. Work to an effective depth of at least 10 feet.

3. Offer a good probability of finding the victim (at least 80% chance of success).

4. Be operational under adverse weather conditions (40 mph wind, -30^{o} temperature, snowfall).

5. Be operational on steep grades (35^{o} slope).

6. Sustain operation for at least 18 hours.

7. Be capable of finding several victims in a given small area.

8. Be storable with minimum maintenance and deterioration.

9. Be available at reasonable cost for the detecting apparatus.

10. Have a low unit cost for any signal device carried by the victim.

11. Be simple in operation.

12. Require a minimum of prerequisite measures to be taken by the victim.

13. Be easy to transport by a single man on skis.

14. Offer no inconvenience for transport of any object carried by the victim.

15. Have no adverse effects on the victim.

Possible detection schemes fall into two categories:

A. Victim does not carry any object specifically related to detection.

B. Victim carried a special signaling device.

Obviously, a workable detection scheme based on the first category is more desirable. At present, all proposed schemes, regardless of category have certain shortcomings. Some are totally inadequate, including the repeatedly advanced suggestion that a radioactive tracer be carried by the victim. The following sections review the various technical possibilities.

In Category A the following possibilities exist.

2.6.1 Sound Emission

Conscious buried victims can often hear sounds of the rescuers above. Sound transmission in the opposite direction is much poorer, but from very shallow depths the victim can sometimes make his shouts heard. He can seldom be heard if deeply buried. Rescue groups can utilize the former possibility by calling out to the victim and listening carefully. Even if the rescuers listen with an audio amplifier this method has its limitations, for the victim cannot respond if unconcious and will quickly use up his limited oxygen by shouting if he does respond.

A more reliable sound source is the victim's heartbeat. Theoretically this ought to be detectable at the surface with sufficiently sensitive apparatus. But the limitations of poor energy coupling between victim and surrounding snow and strong absoprtion in the snow itself, coupled with external noise sources, would make this a very uncertain detection method.

2.6.2 Heat Radiation

A living body is at a higher temperature than the snow and emits infrared radiation to its surrounding. Unfortunately snow is such an efficient absorber of infrared that it is practically opaque at these wave lengths. This effect would not be detectable more than a few millimeters from the body.

2.6.3 Head Conduction

Conduction of heat from the buried victim eventually will alter locally the surface temperature of snow <u>if the snow is subfreezing.</u> Wet snow at

the melting point will only melt from any added heat. In the case of cold snow, disturbance of the temperature field by presence of the victim as a heat source theoretically ought to be detectable. In practice, any such effects might take hours to become recognizable with normal instrumentation. Even more severe is the problem raised by initial temperature inhomogeneities and the strongly disturbed avalanche debris snow. Heat conduction does seem to be a likely means of locating the victim.

2.6.4 Gravitation

The human body is approximately three times denser than cold, dry avalanche snow. Under ideal conditions a highly sensitive gravimeter might be able to detect a gravity anomaly resulting from presence of a buried victim. Gravity measurements are slow, require a skilled operator, and the equipment is very expensive. At best, the victim could be detected only under ideal conditions, for local terrain anomalies would dominate the gravitational field in most cases.

2.6.5 Chemical Odor

The avalanche dog successfully uses this principle, so it is known to work. No mechanical contrivance has yet been assembled which can duplicate the nose of a good dog. But the proven feasibility of locating victims by chemical odor suggests that this might be a more profitable avenue of investigation than the ones previously described. A sensitive detector of local carbon dioxide concentrations has been proposed as one attack on this problem. The method offers some possibilities, but no equipment has yet been produced for operational tests. A recent military device which reacts in very sensitive fashion to the ammonia in human perspiration might also merit tests for avalanche rescue.

2.6.6 Reflected Sound

The sonar principle widely used for undersea detection might work in avalanche debris. A sound signal emitted at the surface would generate reflections from density or surface character variations within the snow, including a victim's body. Limitations on this method include the very short ranging distance, strong absorption of sound by snow, confusing reflections from natural inhomogeneities in avalanche debris, and the well-known difficulties of coupling appreciable amounts of sound energy into snow.

2.6.7 Reflected Electromagnetic Radiation

Most parts of the electromagnetic spectrum are unsuitable for use in snow. Ultraviolet and infrared (see 2.6.2) are strongly absorbed over very short distances. Visible light penetrates a long distance in snow, especially in the blue part of the spectrum, but is so strongly scattered by the snow crystals that buried objects are completely obscured by an inch or two of snow. Satisfactory transmission is possible in certain regions of the radio spectrum, so the radar principle could be applied in theory to locate a victim. The very short distances involved in avalanche search require pulse

lengths and return times so short (10-9 to 10-10 second) that they probably lie beyond the scope of present radar technology.

2.6.8 Dielectric Effect

The dielectric constant of water (the human body--approximately) and that of ice are nearly the same for the very high and very low ends of the electromagnetic spectrum. They differ widely over a middle range of the spectrum in the neighborhood of 10 mHz (short-wave radio frequencies). C. Jaccard of the Swiss Avalanche Institute has pointed out some possible detection schemes which take advantage of this difference, but at the present they have not yet been brought to practical trial.

Category B includes some promising technical means of locating avalanche victims, but all of these encounter a basic practical difficulty in that they require the potential avalanche victim to equip himself in advance with some special device. Technological and cost problems raised by this requirement may be solvable, but the psychological problem is formidable. Just those persons most in need of avalanche accident protection--the untrained, the unaware or the over-confident--are the ones least likely to seek special protective devices.

2.6.9 Magnetic Detectors

If the avalanche victim carries a strong permanent magnet he can readily be located at burial depths up to 8 feet or more by a portable magnetometer. The feasibility of this system has been recognized for a number of years. Practical search systems are currently offered by Varian in the United States and Foerster in Germany. The magnets are inexpensive and require no maintenance. Rather careful scanning of the avalanche debris is required, for the radius of the detectable magnetic signal is comparatively small. Some training and practice on the part of the magnetometer operator facilitates rapid search, but the instrument is very simple to operate. The principal disadvantage of the magnetic search system is the very high cost of the magnetometer, from $5,000 to $8,000 at current United States prices. This severely limits the number of search instruments which can be stocked in avalanche caches. In many instances the cost rules out use of the magnetometer.

2.6.10 Radioactive Tracers

The idea of using Geiger-Mueller counters or scintillometers to search for a radioactive source carried by an avalanche victim has been repeatedly advanced. In fact, while theoretically feasible, this method is practically one of the least attractive of the various search schemes. Water, including water in the form of snow particles, is an efficient absorber of gamma radiation. (Alpha and beta rays for practical purposes do not penetrate water at all.) Any gamma ray source strong enough to penetrate several feet of avalanche snow and be detectable at the surface would have to be so strong that it would pose a serious radiation hazard not only to the bearer but to anyone else in his vicinity. This obstacle cannot be overcome by

reducing intensity of the source and increasing sensitivity of the detector. Normal background radiation from the atmosphere places a definite lower limit on the strength of signal which can be detected.

2.6.11 Mechanical Signal

From the purely practical standpoint, there is one unquestionably superior method of locating a buried victim--the avalanche cord. The cost is insignificant and the method has repeatedly been demonstrated by test and actual use to be reliable. The biggest advantage of all is that no special search equipment is required. Survivors of an accident can start looking for the victim's avalanche cord as soon as the flowing snow comes to rest. A disadvantage is the inconvenience of a 50-foot cord trailing behind a skier. This can lead to some unpleasant surprises if the cord becomes entangled in a tree while the skier is moving rapidly. Avalanche cords have saved lives--they definitely work. But the history of avalanche accidents lists surprisingly few cases involving avalanche cords. People who take the trouble to wear avalanche cords seldom get caught in avalanches. This is a corollary of the psychological problem mentioned above.

Various schemes have been advanced to improve the convenience or effectiveness of avalanche cords. These include suspension from helium-filled balloons and the launching of a miniature line-carrying rocket by the victim as he is swept away in an avalanche. The balloon scheme has actually been tested. It works, but doesn't solve the tree problem and may in fact compound it. The practical gains over a simple avalanche cord probably do not merit such complex innovations.

2.6.12 Chemical Signal

There is a possibility of increasing the effective working depth of avalanche dogs by having the victim release a strong artificial scent which would carry farther through the snow than the normal human odors. The problems are to find such a scent which would be attractive to dogs without leaving the human socially unacceptable, and which could be automatically released in an avalanche. The automatic release problem may be insoluble--the mechanism would have to distinguish between the shock of an avalanche and that of a normal ski fall. Voluntary release by the victim as the avalanche overwhelms him, like the firing of the rocket mentioned above, seems rather impractical.

2.6.13 Sound Emission

An audible sound emitter such as a buzzer or electronic siren could be carried by the victim. If sufficiently powerful, it might be detectable at the surface with a suitable listening device. A big problem would be providing sufficient power in a portable device. The problems of automatic triggering mentioned in 2.6.12 would also apply.

2.6.14 High Frequency Radio Emission

From the technical standpoint this is one of the most promising search methods. A miniature radio transmitter carried by the victim can quickly be located with a simple transistorized receiver. This technique has been tested and found effective. The transmitter can be very compact--even pocket size--but does require an antenna loop sewed into a parka or shirt. If the transmitter operates on a broadcast band frequency, an inexpensive transistor radio will serve as the receiver. The highly directional character of the ferrite core antenna found in most small radios aids in locating the transmitter. Only very low power from the transmitter is needed (and in fact is severely limited by law), so it will operate for many hours from miniature batteries. Rechargeable nickel-cadmium batteries are preferred because they are much less affected by low temperatures than normal dry cells. Legally-permitted radiation at the lower end of the broadcast band can be detected with an ordinary transistor pocket radio up to about 50 feet from the transmitter. This is a substantial improvement in search radius over the magnetic methods. Because prolonged transmission is possible, the triggering problem is eliminated. The carrier of the transmitter can switch it on whenever he enters an avalanche danger area and leave it on until he leaves. Limitations of the radio detection method are the restricted amount of permissible radiated power and the necessity of carrying a separate radio receiver for detection. There are also problems of signal absorption in wet snow or by other buried objects. Like all Category B search methods, this one is limited largely to organized groups which can provide the necessary equipment to persons exposed to avalanche danger.

2.6.15 Audio Frequency Induction Field

A research team at Cornell Aeronautical Laboratory (Buffalo, New York) under the direction of Dr. John Lawton has recently proposed a search method which removes the limitations of the radio detection technique. This replaces the radio transmitter with a 2 kHz audio signal generator connected to a transmitting loop similar to the radio antenna. The receiver is a high-gain audio amplifier connected to the same loop and housed in the same case as the transmitter. Power is provided by miniature rechargeable batteries which permit 200 hours of transmitting and 1500 hours of receiving between charges. Working units (Figure 19) of this system have been furnished by Cornell Aeronautical Laboratory for operational test by professional ski patrols and Snow Rangers during the winter of 1967 and 1968. The designation SKADI, derived from Norse mythology, is the name of the wife of Ullr, so-called patron saint of skiing.

Use of audio frequencies removes the legal limitation on radiated power. The induction field is virtually unaffected by any surrounding medium. It is detectable through 300 feet of solid rock and presumably through any conceivable avalanche debris under which a victim might be buried. Tests to date have shown the system to be highly effective. The signal of a buried transmitter can be detected up to 300 feet away. A completely inexperienced operator can follow this signal to its source within a few

minutes by following changes in signal strength as he approaches or moves away from the transmitter. A 300-foot search radius enormously reduces the search time of a large debris field over other current methods, including the avalanche dog.

In practice a team working in avalanche hazard areas would each carry a SKADI unit. During periods of danger all would be transmitting. If one person were buried in an avalanche, the others would switch to the receive mode (by transferring the antenna coil plug to another socket) and immediately begin the search. With some practice it is possible to separate and locate individually the signals if more than one transmitter is buried.

This detection system is highly promising for use by organized groups such as professional ski patrolmen, Snow Rangers and highway maintenance crews whose daily work brings them into frequent contact with avalanche danger. The requirements for specialized equipment would limit its use by the general public. Negotiations are currently underway with a manufacturer to produce the SKADI system on a commercial basis. The unit price may be in the neighborhood of $25.00.

3. REVIVAL AND EVACUATION OF THE VICTIM

Suppose an avalanche victim has been located and uncovered within an hour of the accident by an efficient First Stage rescue group employing the techniques outlined in Section 2. Will the victim survive? The answer may well be determined by what takes place in the next few minutes.

The victim's appearance may be deceiving. The ordeal of being carried down by an avalanche and buried alive can give a ghastly appearance to the stoutest features. Mechanical injury may have been added to suffocation. To all external appearances, the victim may exhibit no signs of life. The rescuers must begin resuscitation measures even before the victim has been completely cleared of snow, regardless of initial appearance. Unless such unmistakable signs of death as rigor mortis are present, pronouncing the victim dead is better left to a physician (who hopefully has reached the scene by at least Stage Two of the rescue).

Resuscitation procedures should continue until either the victim has been revived--the efforts are obviously hopeless (after at least an hour)--or a physician has pronounced him dead. If the victim is revived, intensive care and treatment are still vital to insure his ultimate survival. Normal first-aid measures for injury and shock are imperative. Special care must be exercised to restore the victim's body heat, for severe cooling often is a consequence of avalanche burial. The victim must be transported to a hospital with care and must be attended closely during transport in case of relapse or cessation of breathing.

Review of current avalanche rescue practices and equipment in the United States suggests that the weakest part of procedures, training and equipment is in treatment of the recovered victim. The absence of adequate resuscitation equipment in avalanche caches, and the provision of no more than the first-aid supplies and transport equipment common to ski injuries, are now beginning to be remedied in many areas. In publishing these guidelines for modern avalanche rescue, we explicitly wish to place strong emphasis on the principles of adequate resuscitation measures and treatment of avalanche victims.

The following sections have drawn heavily on the discussion of avalanche victim medical problems published as a paper entitled "Wiederbelebungsmassnahmen bei Lawinenverschuetteten" ("Revival Measures for Persons Buried in Avalanches") in the Eigenmann Symposium Proceedings (11). This paper was written by Dr. G. Hossli, Director of the Anaesthesia Department, University Clinic, Zurich. For additional suggestions, comments, and review of these sections, we are also indebted to Burton Janis, M.D. and James Wilkerson, M.D., both from the faculty of the University of Utah Medical School. Dr. Janis is a member of the Mountain Empire Professional Ski Patrol. Dr. Wilkerson is the editor of a recently-published text on mountaineering medicine (12).

3.1 Medical Effects of Avalanche Burial

Statistical data on avalanche accidents show that on one hand chances for survival often exist; on the other hand these chances decrease rapidly with depth and time of burial. Only rarely, in about 1/7 of the cases, are the burial conditions so favorable that the victim stands any chance at all of survival after two hours. This is understandable if one realizes that death in avalanches is caused 80 percent of the time by suffocation. Other causes of death may be serious injuries with bleeding, skull and cerebral injuries, overchilling and exhaustion. The exact cause of death in these circumstances is often speculative. Hopefully, with the more intimate involvement of medical personnel, more autopsies of the victims will be obtained; this will then provide precise information about which vital organs fail and how they fail. Such information is needed to give the rescuer the background necessary for more specific treatment.

Suffocation in avalanches is a protracted phenomenon which can be reversed by quick and proper procedures. Knowledge of these procedures and ability to execute them is essential to persons engaged in avalanche rescue work. As is the case with other suffocation situations (for example, drowning, traffic accidents, poisoning, electrical accidents), this type of life-saving first aid is often successful. Suffocation means lack of oxygen and a simultaneous increase of carbon dioxide in the tissues of the body, caused mostly by a hindrance of respiration. In the case of avalanche burial, this can be caused by the following:

1. Penetration of snow (-dust) into the mouth, throat and deeper air passages. This is often made worse by spasm of the glottis.

2. Pressure of the snow masses on the thorax, especially in depth and during the stopping of the avalanche. (1 m^3 of snow can weigh several hundred kilograms).

3. Consumption of the small quantity of air in the space around the face.

4. Blows to the head with subsequent unconsciousness (obstruction of the air passages by swallowing the tongue and recession of the lower jaw in upside-down position), vomiting or loss of breathing due to cerebral damage.

Complete blocking of ventilation or insufficient breathing always produces characteristic suffocation signs. The cerebral nerve cells are most sensitive to oxygen deficiencies. Accident victims lose their consciousness after 45 to 60 seconds following stoppage of the breath; after about three minutes the first permanent brain damage occurs; and after a period of more than eight minutes one can no longer count on survival, even if it were possible temporarily to start the breathing and circulation again by means of resuscitation measures. The critical time, during which attempts at revival are promising, is only about three minutes. However, in case of avalanche accidents, two factors can prolong the survival time and thereby

increase the chance of success of later rescue measures:

1. If the snow cover is not too thick or too dense, the buried person will breathe longer, however insufficiently, than would be the case if the air were completely cut off; the same applies if the accident victim is able to maintain a larger air space around his face.

2. If the buried person loses consciousness, mainly because of insufficient breathing, heat-producing defense mechanisms--for example, shivering due to the cold--are inhibited; this results in a thorough cooling of the entire organism. This extends life to a certain degree because the lowering of the body temperature also decreases the metabolic processes and the available oxygen suffices for a longer period of time. While this cooling tends to prolong life, it also poses a problem to the rescuer. The victim's body heat must be restored to aid revival. Simply protecting the victim from cold is not enough--he must be warmed by careful application of external heat.

In the case of many persons saved after burial by avalanche, this life-prolonging condition of the "apparent death" with a lowering of the signs of life to a "Vita minima" has actually occurred. There was the case of a woman skier who was rescued after twenty hours of severe chilling and who was saved despite prolonged unconsciousness. In February 1963, a Swiss soldier buried by an avalanche for eight hours was dug out from a depth of 1.5 meters and saved; he had quickly lost consciousness; the body temperature at the time of rescue was between 30 degrees and 33 degrees centigrade; the blood pressure 80/65 mm Hg; the pulse rate 44 per minute; the breathing was extremely superficial and slow. Similar cases are continuously reported by members of rescue teams in avalanche accidents.

3.2 Initial Treatment of the Victim

During the first urgent treatment of a victim after burial by an avalanche, as is the case in other resuscitation situations, measures for restoring sufficient ventilation are most important. This is because restoring gas exchange in the lungs is the prerequisite for a recovery of circulation, and because the breathing can usually be brought under control by non-medical helpers and with simple manipulation. These measures are begun as soon as the head of the victim is exposed.

The wiping out of the mouth and throat with the extended finger covered with dry gauze or a handkerchief is often not sufficient for opening the breathing passages, where the mouth and throat of the accident victim are full of snow-water, blood or vomit. In this case, a simple, light, small, efficient and reliable foot suction pump gives good service. If the foot suction pump is not available, then one should attempt to suck the liquid from the throat and pharynx with a catheter or with a thin rubber tube. Since the suction pump is independent of foreign power sources and since it leaves both hands free, a single helper can operate it reliably at the

scene of the accident or in the transportation vehicle. This, as well as the suitable positioning of the unconscious person (lateral position and as much as possible simultaneous low positioning of the upper part of the body and head with fixation through straps over the hip to the stretcher and the sled) should avoid renewed blocking of access to the larynx (keeping open the breathing passages). This practically eliminates the penetration of water, blood, vomit, or foreign bodies into the deeper breathing passages (so-called aspiration) with the danger of suffocation or subsequent pneumonia. Often it is not possible permanently to keep the air passages clear in this manner (transportation, restless patient). In this case, the auxiliary aid of an oropharyngeal tube (airway - resusitube) introduced into the throat will help to keep the air passage clear, both during resuscitation and after normal breathing has been restored.

Time must not be lost unnecessarily with suction attempts, which in any event are indicated only in certain cases with obvious obstruction of the respiratory passages. Much more important is the immediate starting of respiration if the spontaneous respiration of the patient has become superficial or has ceased altogether.

While awaiting the arrival of the respiration equipment, which should permit one helper to administer adequate and effortless breathing for hours, an attempt should be made to ventilate the lungs without the use of auxiliary equipment. For this, mouth-to-mouth resuscitation is best. This is started immediately as soon as the rescuer has access to the head of the patient, while the other members of the rescue team dig out the buried body. Breathing into the mouth is also possible if the victim lies in a lateral or abdominal position. If the insufflation meets resistance, the head-jaw position must be improved by overextending; it is also possible that the air passages are blocked by snow or other foreign bodies. This necessitates an inspection and cleaning out of the pharyngo-oral space. Artificial respirtation without open air passages is pointless. The first puffs of breath are often decisive. Therefore, the victim is respirated; immediately at least 10 times in quick succession with the mouth before a more normal and slower rhythm of about 10 to 12 breaths per minute is started. In order to avoid direct contact with the victim, a handkerchief, a few layers of surfical gauze, or any other piece of textile which is permeable to air may be placed over the nose and mouth of the victim.

The possibility of mechanical injury is always present in an avalanche victim. The rescue team should exercise special care to check for the possibility of neck fracture before manipulating the patient to clear the air passages and begin resuscitation. If a neck fracture appears possible, traction is permissible, but flexing of the neck should be minimized. If breathing has stopped, resuscitation must begin in any case, but with great care if neck injuries are suspected.

Resuscitation already started without the aid of auxiliary equipment can become more effective and less troublesome for the attendant by the use of respiration equipment. In the case of simple bag or sac equipment, breathing takes place by insufflation of air into the lungs. The important advantage

of all insufflation methods, which also applies to mouth breathing, is that the helper is forced to continually see to it that the air passages are kept open. The effect of breathing can be judged at all times by the movements of the thorax, the exhaled air and by the general appearance of the patient. Atmospheric air is in almost all cases sufficient for the revival. The oxygen saturation in the arterial blood, which normally in lowlands and in normal spontaneous breathing amounts to about 97 percent, begins to drop below 90 percent only at an elevation of 11,500 feet above sea level. In this instance, the addition of oxygen becomes advisable. However, in the usual respiration cases, it is possible to obtain a sufficient blood-oxygen saturation with light, forced breathing with air alone up to an elevation of about 19,000 feet. Air is present everywhere and there is never any shortage. If oxygen is available it may also be administered as an extra measure at high altitudes, but the resuscitator, not the oxygen bottle, is the important equipment to get to the victim first. There is an additional reason to make sure a resuscitator is on hand when the victim is located. If no such equipment is available and mouth-to-mouth resuscitation must be used, the deleterious effects of high altitude are apt to appear much more quickly in the operator than in the reviving victim. Above 10,000 feet the operator administering mouth-to-mouth resuscitation very quickly becomes exhausted. If prolonged resuscitation without equipment is required, the rescue team should rotate operators at the respiration task every few minutes.

The type of resuscitator using a self-inflating bag (AMBU, Hope, etc.) is preferred because it is less fatiguing to the operator and offer greater tactile sensitivity. In addition, the breathing rhythm is forced within certain limits by the elasticity of the bag, so that the danger of under or over-respiration is lessened over a long period of time. The breathing bag and its accompanying equipment also function properly where extensive soiling exists and under the most varied weather conditions.

Respiration must be continued without interruption until natural breathing sets in fully again, or until unmistakable signs of death occur.

Even if the victim shows slight signs of life (swallowing, bumping, slight movements) or if he breathes weakly, one must continue with the artificial--in this case supported--respiration. Simultaneously, the appearance of the lips, tongue and fingernails is observed. Respiration and circulation are substantially improved if the blue discoloration disappears and the normal rosy color returns.

If an avalanche victim is recovered in a state of cardiac arrest (no pulse or heartbeat, pupils dilated) the chances of successful resuscitation may be augmented by closed-chest heart massage. This procedure should be undertaken only by a properly-trained person (preferably a physician) and should begin immediately along with artificial respiration (cardiopulmonary resuscitation). Because this technique involves the possibility of such injuries to the victim as broken ribs or liver damage, current medical opinion in the United States (and in Switzerland) does not advocate teaching cardiopulmonary resuscitation procedures to the general public.

For this reason both the American Red Cross and the National Ski Patrol system specifically exclude such procedures from their training programs. On the other hand, both the National Academy of Sciences (Reference No. 7) and the American Heart Association (Reference No. 3) have recommended that rescue workers be taught the techniques of closed-chest heart massage. Individual rescue organizations will have to reach their own decisions about seeking such training. We can only point out here that there is indisputable medical advantage to a cardiac arrest victim in properly applied cardiopulmonary resuscitation. The alternative to restored heartbeat is death.

3.3 Post-Resuscitation Care

After the rescue, the accident victim is positioned flat, if possible, with the upper part of his body slightly lowered. The blood circulation can be stimulated by massaging the arms and legs from the periphery toward the heart.

Any further chilling has to be avoided. The victim's reaction to fight the cold consumes large amounts of energy. Existing heat not only has to be conserved, but external heat has to be supplied to counteract the body cooling. A warm sleeping bag is essential. This may be heated by chemical hot pads or hot water bottles, or by preliminary occupation by a healthy person. A large sleeping bag is preferred, for then it is possible for one of the rescuers to get in with the victim to help warm him. When external heat sources are used, especially hot pads, care must be exercised to avoid local overheating. Wet cloths should be removed from the victim, his body dried, and dry clothing (blankets, down garments) provided. Shelter from wind and snow is an obvious essential for such care of the victim. A small, light-weight tent which can be quickly erected at the accident scene is very useful, as well as a small, portable stove (butane, gasoline) to heat it.

As long as the victim remains unconscious, full attention has to be paid to keeping the breathing passages open and to the possible need of administering further artificial respiration. The unconscious person is positioned on the rescue sled and on the stretcher in a horizontal prone position with neck slightly extended and tied above the hip with belts or cloth; the head and upper part of the trunk lie flat or are even inclined slightly downward. According to his condition, the rescued person is transported to the hospital or to his home in the company of an attendant who observes him continually. In either place, medical supervision must be continued.

The rescuers should be alert for head, neck and back injuries. If the latter are suspected, particular care should be used in moving and positioning the victim. In the case of mechanical injuries in general, the conscious victim should be positioned for transport in the most comfortable position.

3.4 Summary and Equipment

1. The probability of survival decreases rapidly with the duration of burial time; it is already extremely slight in the case of a rescue after one to two hours. However, since savings of victims have been reported in isolated cases after more than 24 hours, the rescue attempts should be carried out with full vigor for at least this span of time. If only the head of the buried person is freed, the revival measures should be started at once and continued uninterruptedly until the victim either revives or signs of death are determined with certainty.

2. Respiration begins at once by insufflation. Without the aid of auxiliary equipment it is carried out by mouth-to-mouth or mouth-to-nose breathing. If the air passages are obviously blocked, the inspection of the pharyngo-oral area and the removal of foreign bodies, sometimes with the help of a suction pump, is required.

3. Respiration with air suffices in all cases with open air passages for resuscitation in the mountains up to an elevation of 19,000 feet. Oxygen may be administered as a supplementary aid if available.

4. Unconscious persons with sufficient spontaneous respiration are placed in a horizontal prone position; if possible, with slightly lowered position of the head and upper part of the trunk, and are transported in the same position.

5. Further chilling is to be avoided. Careful administration of external heat is preferred. Stimulative and warming beverages may only be given after the victim has regained consciousness and a positive determination has been made by a physician that there are no internal injuries.

6. Resuscitation equipment consists of the following items:

   A. Breathing

- Suction pump with suction catheter - Breathing bag with air and oxygen inlet and breathing valve (resuscitator complete with accessories) - "Airway" or "Resuscitube" breathing tube	-- For the non-medical rescue worker
- Instruments for endotracheal intubation	-- For the physician

B. Infusion

- Plasma solution with discardable instruments (plasma must be stored under refrigeration)

- Injection syringes, infusion and other canula, bandages, splints and adhesive plaster, tincture of green soap.

C. Medicines

- Peripheral circulation agents, cardiac stimulants, pain relievers with antidotes, central analeptic

D. Supervision

- Blood pressure measuring apparatus (portable) with flat stethoscope

- Flashlight

- Note paper, etc. for injury records, wax pencil or cardboard tags to record time of drug administration

-- For the physician

Detailed lists of recommended contents for the resuscitation pack and the physician's medical kit are given in Appendix i. Further details concerning specifications and sources of equipment are in Appendix i.

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ADDENDUM

Another innovation in avalanche safety has been announced as this Snow Safety Guide is going to press. The Alta Avalanche Study Center has received from the Vanni Eigenmann Foundation an experimental set of "Gramminger-Hauser" ski poles for test and evaluation. Each pole contains 50 feet of avalanche cord in the handle, the end of which is attached to the leather wrist strap. If the wearer of the pole and wrist strap is caught in an avalanche, a jerk on the strap frees the cord from the pole and allows it to unwind as the pole is carried away in the avalanche. A special noose design of the strap insures attachment to the wrist.

The handles and baskets of both poles can be removed and the two poles joined by a bayonet connection to form an avalanche probe nearly 8 feet long. A special ventilating device at the lower end of this pole allows air to be conveyed to the victim when he is located under the snow by the searcher blowing in the top.

If a skier uses these poles and in addition continues to display a standard avalanche cord when entering a hazardous area, it seems highly probable that at least one of these cords will reach the surface in an avalanche burial situation. In addition, two conveniences are gained from the "Gramminger-Hauser" poles:

1. Users need not remove wrist straps when entering hazardous areas.

2. Users need not carry separate probes on ski tours.

A report appraising the effectiveness of these poles will be issued after tests have been completed.

APPENDIX i

Equipment

(a) Specifications, Sources, and Costs

Specifications, sources, and costs of equipment typically suitable for avalanche rescue are tabulated below. This list is furnished for the convenience of purchasing officers in planning costs and procuring supplies. Mention of specific products and supplies does not constitute endorsement by the U. S. Department of Agriculture. Other products with the same characteristics may be used as well. Although sometimes more expensive, lightweight equipment should be given preference over similar heavier versions. In addition, the selected equipment should be simple to operate and able to withstand the rigors of winter rescue.

Equipment	Specification	Source	Cost
Avalanche Cord	Perlon avalanche cord. Red braided cord with markers every 6 feet showing the distance and direction to the victim. Made by Edelrid.	Recreation Equipment, Inc. 1525 11th Ave. Seattle, Washington 98122	B088B19 52 ft. long $1.10 B088B20 100 ft. long $1.95
Avalanche Probes (Collapsible)	20-inch sections joined by steel cable. Total length extended, 10.5 feet. Cable tightened by wing nut.	Colorado Mountain Sports, Denver, Colorado	$8.50 per probe
Avalanche Probes (one piece)	See Page 6 .		
Avalanche Probes (Sectional)	Mast section MS-116A. Sectional antennas in 3-foot lengths, screw together. These are exceptionally strong and durable.	Henry Products Company - 850 Rockaway Ave., Brooklyn, N.Y.	$4.50 per section
Climbing Rope	Plymouth Goldline. 3/8" x 150'--5½ lbs. B586A6.	Recreation Equipment, Inc. 1525 11th Ave. Seattle, Wash. 98112	$15.00

Equipment	Specification	Source	Cost
Climbing Skins	Army mohair climbers. Adjustable for size. Two sizes: 6' to 6' 7", 6' 9" to 7' 3". T711E9, specify size.	Recreation Equipment, Inc. 1525 11th Ave. Seattle, Washington 98122	$4.95
Compass	Personal preference, or: Suunto (geological).	Alpine Hut, Inc. 4725 30th N.E. Seattle, Washington	$8.25
Emergency Resuscitator and Aspirator	Ambu emergency kit. Consists of two parts--a respirator and an aspirator. Aspirator has foot operated suction pump. Oxygen bottles can be attached to respirator, but not necessary for its operation. Weight about 10 pounds. Resuscitator - 13-100-70 Suction pump - 13-200-70 Carrying case - 13-031-03 (Available to Government agencies at reduced price through Contract No. GS-00S-72118).	Air Shields, Inc. Hatboro, Pennsylvania	$73.00 $87.00 with case.
First-Aid Belt	National Ski Patrol type.	National Ski Patrol System, 828 17th Street, Denver, Colorado	About: $4.50

Equipment	Specifications	Source	Cost
Flare Launcher	25 mm flare launcher, shoots flare a distance of 250+ feet, 10,000 foot candles, visible over 1,200 square miles. No. 25-MP, includes: pistol, 3 meter flares, 1 parachute flare. Replacement flares: No. 25M-MR, box of 6, red.	Signal Products Operations (a Division of Olin Matheson), East Alton, Illinois	$27.95 Replacement flares: $9.00 per box
Headlamp	Justrite Headlamp. Uses 4 D cells in metal case, slips on belt, 120 t. L518C28. Similar unit available to Government agencies through contract. GSA 6230-643-3562.	Recreation Equipment, Inc. 1525 11th Ave., Seattle, Washington 98122	$3.95 each
inflatable Splints	Arm splints, SA 1; leg splint, SA 2.	Sumilaids - Woodstock, N.Y.	SA 1 - $1.50 SA 2 - $3.00
Lantern (Coleman fuel)	Coleman Lantern	Most sporting goods stores	About $15.00
Lantern (Butane Cartridge)	Blenet Gas Lantern. 12" high, with carrying handles, uses butane cartridge, burns about 6 hours per cartridge. Weight, including cartridge - 2 lbs. 5 oz. Lantern complete L509C9. Extra cartridge - H509A20 Extra mantle - L509C10 Extra globe - L509C11.	Recreation Equipment, Inc. 1525 11th Ave. Seattle, Washington 98122	L509C9 - $12.95 H509C10 - .60 L509C10 - .17 L509C11 - .98

Equipment	Specification	Source	Cost
Maps	Most areas in U. S. are covered on 15 or $7\frac{1}{2}$ minute contour maps published by the U. S. Geological Survey.	U.S. Geological Survey - Building 25 Denver Federal Center, Lakewood, Colorado	$.30 to $.50 per sheet
Marker Flares	Fusee backfiring torch. 72 torches per box. Weight per box 36 lbs. 10 minute burning. (Available to Government agencies on Contract No. GS-085-23000. Order No. 0-862960-A. Stock No. 1370-294-1279).	Standard Railway Fusee Corporation - Fostoria, Ohio	$.35 each at army surplus or auto supply stores
Molded Plywood Packboards	"G.I. Type", without pack sack.	Most army surplus stores	About $9.00
Plastic Snowshoes	"Snow treads"	Snow Treads, Inc. Box 1082 Boulder, Colorado 80302	$15.00 each
Power Megaphone	Heavy duty, transistorized, hand-held, portable power megaphone. 112 decibel output, 7 lbs. without batteries, 15 inches long. Diameter of reproducer bell is 12 inches. (Covered by GSA Contract No. GS-00S-38981.)	Audio Equipment Company, Inc. - Port Washington, N.Y.	$203.00 GSA Contract Price
Propane Floodlamp	White light, 15,000 ft. candle power, 50 hours on 20 lb. cylinder. Cylinder with gas weighs 45 lbs. Model BL130 made by Lee Light.	Local petrolane dealer	$176.50

Equipment	Specification	Source	Cost
Resuscitube	Johnson and Johnson	Most drug stores	\$1.50
Sectional Toboggan	Light weight, two sections. Suitable for attachment to pack frames. Commercially available in Europe, but a difficult item to purchase in U.S. Individual rescue organizations may fabricate their own models.		
Snow Shovel	D-handle, aluminum shovel with square blade. Ames No. 16-387.	Local hardware distributor	\$4.50
Stokes Litter	Junkin Safety Appliance Company SAF 300.	Junkin Safety Appliance Co. - Louisville, Kentucky; or sometimes army surplus stores	\$42.80
Wand (Flag attached)	Wire staff, 30 inches long. Fluorescent red flags, 4" x 5". (100 flags make a bundle 1" in diameter.)	Blackburn Manufacturing Company - P. O. Box 224 Neligh, Nebraska 68756	\$1.65 per 100

(a) Specifications, Sources, and Costs (Continued)

AVALANCHE PROBE POLES

1/4" 606-1T6, schedule 40, Aluminum Pipe X 12 feet
Weight per 12 foot - 1.76 pounds.

Actual size - O.D. - .540"; I.D. - .364

Cost:

Under 25 lbs.	25 - 49 lbs.	50 - 99 lbs.	100- 199 lbs.
$31.01/C ft.	$24.86/C ft.	$21.13/C ft.	$18.65/C ft.

Freight paid on 100 lbs. or more -
1 week delivery.

Source:

Tubing Distributor

Example of costs: 10 probe poles, 12 feet long

Weight per 12 ft. pole - 1.76 lbs. x 10 = 17.6 lbs. Hence use rate of 31.01/100 ft., under 25 lbs. in weight.

12 ft. per pole x 10 = 120 feet.

$31.01 x 1.2 = $37.21 F.O.B. Denver.

Thus, 10 probe poles, each 12 ft. long, will cost $37.21 F.O.B. Denver.

(b) <u>Helicopter Cache</u>

The helicopter cache is essentially a main cache with equipment divided into several cargo loads. Versatility can be achieved if each cargo load pertains to a particular rescue stage--first, second, or third.

At least two strong canvas cargo bags are required:

<u>Cargo Bag 1</u>	<u>Cargo Bag 2</u>
25 Sectional probes	Physician's Kit
25 Headlamps	2 Sleeping bags
2 Shovels	2 Blankets
First-Aid Kit	Sectional Tobbogan
Resuscitation Kit	Splints
15 Flares	
Climbing rope	
Flagging material	
String	
Bundle of wands	

The following should also be on hand at the heliport:

One-piece probes (taped together in bundles)
Stokes Litter
Portable 2-way radio
Extra shovels
Stove, lanterns, rations, etc.

(c) <u>Resuscitation Pack</u>

The following items should be packed in a light weight rucksack, which may weigh at the most 25 pounds:

1. S-tube
2. Oral airway
3. Foot suction pump
4. Resuscitator:
   bag-valve-mask

<u>Optional</u>

Oxygen, adapted to above resuscitator.
Endotracheal tube, adapted to above resuscitator and <u>clearly marked for physician's use only</u>.

(d) Medical Kit List for Physician*

Besides the usual materials carried in the regular first-aid kit i.e., bandages, splints, tape, etc., the doctor's kit should contain the following:

Drugs

Demerol Solution - 50 mg/cc - 30 cc
Demerol Tablets - 50 mg. - 6
Xylocaine Solution - 1% - 30 cc
Epinephrine - 1:1000 Solution - 3 1 cc amps.
Sodium Bicarbonate Solution - 3.75 Gms. - 50 cc - 3 amps.
Amyl. Nitrate - 0.18 cc - 4 aspirals
Iseprel - 1:5000 Solution - 1 cc amp.
Aramine - 1% Solution - 10 cc
Levophed - 0.2% Solution (8 mg.) - 3-4 amps.
Dextrose Solution - 50% - 50 cc
Sodium Chloride - 0.9% Solution for injection - 30 cc
Sterile water for injection - 30 cc
5% Dextrose and water - 1000 cc)------------------ Should include
Sodium Chloride - 0.9% Solution 1000 cc)---------- tubing tape, etc.
Blood Plasma - 250 cc - 2 bottles)---------------- for administration.

Hypodermic Needles

#18 x 1-½" - 3
#20 x 1-½" - 5
#22 x 1-½" - 5
#20 x 6" (Intracardiac) - 2
#20 x 4" (Intracardiac) - 2
#15 x 2-½" (Emergency airway) - 2
#15 x 1-½" (Emergency airway) - 2

Syringes

2-½ cc - 3
5 cc - 3
10 cc - 3
30 cc - 2
50 cc - 1

Supervision

Blood Pressure Apparatus

Flat Stethoscope
Cardboard Tags and Pencil

The procurement, storage, and packing of these items in a suitable rucksack should be supervised by a physician.

*Information compiled by Dr. Bert Janis

APPENDIX ii

STATISTICS

Organized Rescues for Buried Victims in the United States

Snowy Torrent Number‡	Accident Location	Elapsed Time After Accident: Sounding of Alarm (Hours)	Elapsed Time After Accident: Rescuers Arrive At Accident (Hours)	Elapsed Time After Accident: Victim Discovered (Hours)	Outcome of Rescue Efforts: Survivors	Outcome of Rescue Efforts: Died	Developed Area	Back Country
39-1	Mt. Baker, Washington	7	16	16		5		X
53-1	Source Lake, Washington	3	8	8	1	1		X
56-1	Tuckerman's Ravine, N.H.	1	2	100		1		X
56-4	Leeks Canyon, Wyoming	$\frac{1}{2}$	1	50		1		X
58-2	Snow Basin, Utah	1	3	6		1*		X
60-1	Solitude, Utah	$\frac{1}{4}$	$\frac{1}{2}$	$\frac{1}{2}$	1		X	
60-2	Berthoud Pass, Colorado	$\frac{1}{2}$	3/4	1-3/4		1		X
60-5	LaPlatta, Colorado	$2\frac{1}{4}$	11	$11\frac{1}{2}$		1		X
61-1	Aspen, Colorado	$\frac{1}{4}$	$\frac{1}{2}$	3/4		1	X	
61-2	Arapahoe Basin, Col.	immed.	$\frac{1}{4}$	2		1	X	
62-6	Granite Mt. Washington	7	11	12		2		X
62-8	Stevens Pass, Wash.	immed.	$\frac{1}{2}$	$\frac{1}{2}$	1		X	
64-8	Snow Basin, Utah	1	7	20		1		X
64-9	Huntington Ravine, N.H.	22	25	50		2		X
65-1	Sugar Bowl, California	3	$4\frac{1}{2}$	$5\frac{1}{2}$		1		X
65-2	Farmington, Utah	1	2	4	1			X
65-3	Snow Bank, Idaho	$\frac{1}{2}$	$3\frac{1}{2}$	4		1		X
65-6	Mt. Baldy, California	$\frac{1}{2}$	$1\frac{1}{4}$	$3\frac{1}{2}$	1		X	
65-7	Geneva Basin, Colorado	2	3	3		1	X	
65-8	Park City, Utah	$\frac{1}{4}$	$\frac{1}{2}$	3/4		1	X	
66-1	Mt. Baker, Washington	3	8	$8\frac{1}{2}$		1		X
--	Parley's Canyon, Utah	$1\frac{1}{4}$	$4\frac{1}{2}$	$9\frac{1}{2}$		2		X
--	Jackson, Wyoming	$\frac{1}{4}$	3/4	1	1		X	

Organized Rescues for Buried Victims in the United States (Continued)

	Average Elapsed Time After Accident in Hours		
	Sounding of the Alarm	Arrival of Rescuers at Accident	Discovery of Victim
All Rescues	$2\frac{1}{2}$	5	14
Developed Areas	$\frac{1}{2}$	1	$1\frac{1}{2}$
Back Country	$3\frac{1}{2}$	7	20

The following statistics were compiled by Dale Gallagher. They are based on about 60 case histories which appear in the book, The Snowy Torrents. (See Reference No. 1.)

A. Size of slides and fatalities:

42% of all fatalities resulted from slides which ran less than 300 feet.

58% of all fatalities resulted from slides which ran more than 300 feet.

B. Victims buried over two feet deep:

73% died.

C. Depth of burial and recovery time:

2-3 feet burial depth--37% of the victims recovered in less than three hours.

Over 3 feet burial depth--25% of the victims recovered in less than three hours.

D. Position of victim when recovered:

Prone - 71%
Vertical - 19%.
Sitting - 10%.
Victim face down - 94% died.
Victim face up - 36% died.**

‡ See Bibliography Reference No. 1

*In addition, one rescuer was buried by an avalanche on the approach and died after a 45 minute burial.

**This low percentage of fatalities may result from the limited case histories that were sampled. However, a face up burial is thought to be advantageous for survival.

E. Survival versus time buried.

Shaded areas represent the percent of victims that survived the given times of burial.

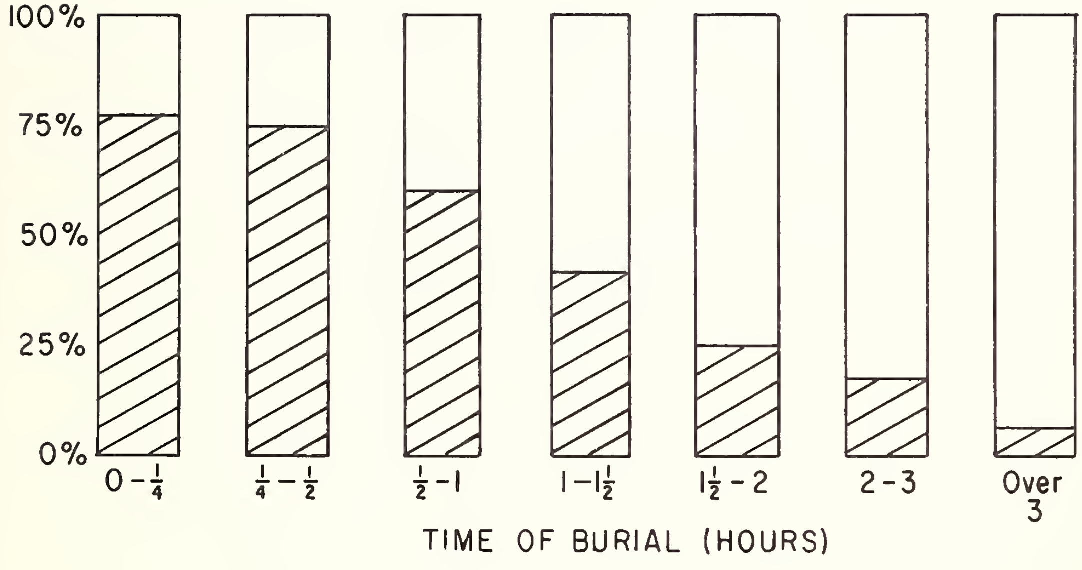

Figure 20. Survival versus time buried. Statistics compiled by Dale Gallagher (Reference No. 1).

APPENDIX iii

ALTA AVALANCHE ALERTING

AND RESCUE PLAN

Season: 196_ to 196_

By: Salt Lake Ranger District

Wasatch National Forest

IMMEDIATE ACTION

1. HOLD THE WITNESS.

2. HOLD RESCUE MANPOWER IN YOUR AREA.

3. SOUND GENERAL ALARM--See Page 3.
   (Lift Operators, see Page 4.)

GENERAL ALARM

CALL ONE OF THE FOLLOWING--start at the top and go down the list until someone is reached:

	Name	Position	Phone
1.	________	________	________
2.	________	________	________
3.	________	________	________
4.	________	________	________
5.	________	________	________
6.	________	________	________
7.	________	________	________
8.	________	________	________
9.	________	________	________
10.	________	________	________

PERSON RECEIVING THIS CALL WILL ASSUME IMMEDIATE LEADERSHIP OF RESCUE OPERATIONS.

GENERAL ALARM--LIFT OPERATORS

1. CONTACT ADMINISTRATION BUILDING BY FIELD PHONE.

2. OPEN AVALANCHE CACHE.

3. REMOVE ENVELOPES OF INSTRUCTION.

4. AWAIT FURTHER INSTRUCTION FROM RESCUE LEADER.

PERSON RECEIVING GENERAL ALARM

1. You are the RESCUE LEADER unless relieved by superior designated on Page 3.

2. TURN ON AVALANCHE ALERT SIREN.

3. DISPATCH FIRST STAGE COLUMNS FROM APPROPRIATE CACHE.

    a. Each column must have a qualified leader.

    b. Each Column Leader is given an envelope of instruction. These envelopes are stored in the caches.

    c. Give each Column Leader directions for reaching the accident site. (It may be necessary to have the witness accompany the first column.)

4. Call for volunteers to assemble at nearest avalanche caches. Use public address system.

5. Obtain two portable radios from the Lower Guard Station. One of these should be taken to the rescue site as soon as possible.

6. Appoint an ACCIDENT SITE COMMANDER. (See Page 8.) An envelope of instruction for the Accident Site Commander is attached to each copy of the rescue plan.

7. Dispatch additional First Stage columns as needed. First Stage columns should travel light, generally carrying only probes and a shovel pack.

8. Obtain resuscitator pack from the Administration Building and give to one of the First Stage columns.

9. Contact physician.

10. Dispatch Second Stage, preferably under the leadership of a physician The Second Stage equipment will consist of:

    Toboggan
    First-Aid Equipment
    Blankets and Sleeping Bags
    Physician's Kit

    plus equipment necessary to reach the accident site.

FOLLOWUP ACTION

Rescue Leader

1. Keep accurate record of times and events.

2. Notify County Sheriff ________________.

3. Notify head Snow Ranger ________________.

4. Notify superiors (see list on Page 3).

5. Notify District Ranger. Home __________
   Office __________

6. Notify Forest Supervisor. Home __________
   Office __________

7. If essential, obtain helicopter assistance (Forest Supervisor's approval required).

   a. ________________

   b. ________________

8. Give out news only as necessary. Do not give out names of victims and their condition until confirmations are made. Refer general news media statements to Forest Supervisor's Office ________________________________.

9. Make arrangements to have transportation ready for injured persons:

   AMBULANCE ____________________

   ____

10. If any of the victims are believed to be dead, notify:

    COUNTY CORONER ____________

    AND IF NECESSARY:

    Dispatch Third State in accordance with instruction on Page 7.

DISPATCH OF THIRD STAGE

Rescue Leader

1. Contact additional manpower. (See list on Page 8.) Instruct to rally at Forest Service Garage (or most suitable location).

2. Notify: The Red Cross--Phone ____________.

3. Procure additional radios from ____________________________.

4. Procure additional equipment from sources on Page 9.

5. Procure food and hot drinks from:

   a. _________________________

   b. _________________________

   c. _________________________

   d. _________________________

   e. _________________________

6. Appoint Third Stage leader. Third Stage leader will direct the distribution and packing of food and equipment at the Forest Service Garage, or most suitable location.

7. Give Third Stage leader the proper directions for reaching the accident site.

QUALIFIED ACCIDENT SITE COMMANDERS

	Name	Alta Phone
a.	____________	____________
b.	____________	____________
c.	____________	____________
d.	____________	____________
e.	____________	____________
f.	____________	____________
g.	____________	____________
h.	____________	____________
i.	____________	____________
j.	____________	____________
k.	____________	____________
l.	____________	____________
m.	____________	____________

ADDITIONAL MANPOWER

Brighton ____________

Mountain Empire ____________

Park City ____________

Wasatch Mountain Club ____________

or ____________

Ute Alpine Club ____________

Utah National Guard ____________

or ____________

LOCATION OF EQUIPMENT

Main Cache: Forest Service Garage--center stall.

First Stage Caches:

a. Top of Germania--on terminal.
b. Top of Wildcat--on terminal.
c. Top of Albion--on terminal.
d. Top of Sugarloaf--on terminal.

Resuscitation Pack and Physician's Equipment:

Administration Building.

Helicopter Cache: Fire Control Center

Additional Caches:

a. Brighton ____________________.
b. Mountain Empire ____________.
c. Park City ___________________.
d. Farmington Experimental Station ____________________.
e. Francis Peak Radar Tower___ ____________________.

Snow Cat:

a. ______________________________

b. ______________________________

c. ______________________________

d. ______________________________

SECURING AVALANCHE OPERATIONS

Rescue Leader and Accident Site Commander

1. Accident site commander must make sure all members of rescue teams are accounted for before leaving rescue area.

2. Accident site commander should be sure all equipment is picked up and returned to base camp before leaving rescue area. All trail markers should be picked up on return trip.

3. RESCUE LEADER MUST MAKE SURE ALL RESCUERS HAVE RETURNED AND HAVE SIGNED IN AT END OF OPERATIONS. VERY IMPORTANT!

4. Rescue leader should notify County Sheriff and Forest Supervisor that the avalanche rescue operations have ceased.

5. Upon return to base camp, all equipment shall be returned to a central location designated by the rescue leader.

6. All equipment borrowed from other areas will be placed in separate piles, and rescue leader will make arrangements for its return.

7. All forms and notes should be turned in to rescue leader upon arrival of rescue teams in base camp. Anyone that has written information should turn this in before leaving the area.

8. Duty Snow Ranger will check all equipment and restore, replace, or repair immediately. Remove all batteries from flashlights and plan for immediate replacement.

9. Secure names of all persons who have been rescued upon conclusion of rescue operations and make arrangements for hospital checkups as soon as practical.

10. Rescue leader should make out final report as soon as possible.

CHECK LIST

Rescue Leader

A. Time Accident Reported: ______________________________

B. Reported by: ______________________________

C. Location of Accident: ______________________________

____

D. Time Accident Occurred: ______________________________

E. People Caught: Number ____________ Names: ______________

F. First Column Dispatched: From: ______________________

Leader: ______________ Members: ______________

G. Additional First Stage Columns:

1. ______________ (Leader)

3. ______________ (Leader)

2. ______________ (Leader)

4. ______________ (Leader)

H. Equipment (First and Second Stages):

a. Probes: ______________
b. Shovels: ______________
c. Resuscitator: ______________
d. Toboggan: ______________
e. Headlamps: ______________
f. Other Equipment: ______________

____

I. Second Stage Dispatched: Time: ______________

______________ (Leader)
____
____
____
____
____
____
____
____
____

J. Notify County Sheriff: ______________

K. Forest Service Personnel Notified: ______________

L. Highway Department Notified (Road Slide): ______________

M. Red Cross Notified: ______________

N. Third Stage Dispatched: Time: ______________

Equipment: ______________

____

____

O. Operations Secured: Time: ______________

1. ALL MEN ACCOUNTED FOR: ______________

2. ALL EQUIPMENT ACCOUNTED FOR: ______________

P. NOTES:

(The following information will be placed in an envelope and attached to the rescue plan.)

INSTRUCTIONS FOR THE ACCIDENT SITE COMMANDER

1. Upon arrival at the accident site, assume command from the column leader in charge.
2. Get complete briefing of the rescue operations.
3. Get manpower lists.
4. Continue direction of coarse probe lines.
5. Establish radio contact with rescue leader as soon as possible. Report progress of search and needs of rescuers.
6. Arrange to remove witness and exhausted rescuers from area.
7. After whole slide has been coarse-probed, reorganize probe lines at bottom and repeat coarse probe process. Resort to fine probe technique when coarse probe attempts have been unsuccessful.
8. If rescue operation appears to be a lengthy affair, arrange with base camp for the organization of the Third Stage.
9. Continue to arrange for the replacement of tired rescuers with fresh men.
10. Dispatch tired men to base camp in groups, under leader. Keep track of who is leaving.
11. At conclusion of rescue operations, dispatch men and equipment to base camp in groups. MAKE SURE ALL MEN AND EQUIPMENT ARE ACCOUNTED FOR.

CHECK LIST

Accident Site Commander

A. Location of Accident: ______________________________

____

B. Party Members:

1.	____________ (Survivor)	16.	____________
2.	____________	17.	____________
3.	____________	18.	____________
4.	____________	19.	____________
5.	____________	20.	____________
6.	____________	21.	____________
7.	____________	22.	____________
8.	____________	23.	____________
9.	____________	24.	____________
10.	____________	25.	____________
11.	____________	26.	____________
12.	____________	27.	____________
13.	____________	28.	____________
14.	____________	29.	____________
15.	____________	30.	____________

C. Surface Search of Slide: From ____________ To ____________

D. Times of Arrival of First Stage Columns:

1. ____________
2. ____________
3. ____________
4. ____________
5. ____________

E. Probe Lines Established (Time): ____________________

F. Victims Found:

a. (Name) ______________ (Time) ____________
b. (Name) ______________ (Time) ____________
c. (Name) ______________ (Time) ____________
d. (Name) ______________ (Time) ____________

G. Time of Arrival of Second Stage Column: ____________

Check List - Accident Site Commander (Continued)

H. Equipment

1. Probes (Number) ________________
2. Shovels (Number) ______________
3. Resuscitator ___________________
4. Rescue Toboggan ________________
5. Search Packs (Number) __________
6. Headlamps (Number) _____________
7. Additional Equipment ___________________________________
____

I. Time of Arrival of Third Stage Column: _____________________

J. Securing Operations: Time: _________

Groups dispatched for base camp:

a. ________________ (Leader)
____
____
____
____
____
____
____
____
____

c. ________________ (Leader)
____
____
____
____
____
____
____
____
____

b. ________________ (Leader)
____
____
____
____
____
____
____
____
____

d. ________________ (Leader)
____
____
____
____
____
____
____
____
____

K. All Men Accounted For: ________________

L. All Equipment Accounted For: ____________

M. Time of Arrival at Base Camp: ___________

N. NOTES:

(The following information will be placed in an envelope. This envelope will be plainly marked: INSTRUCTIONS FOR FIRST COLUMN LEADER. Each cache will contain one of these envelopes, also pencil in each envelope.)

INSTRUCTIONS FOR THE FIRST COLUMN LEADER

You are in charge of the hasty search. With emphasis on speed and safety, proceed as follows:

1. Screen out volunteers who seem unfit for the operation.

2. Equip each volunteer with a probe.

3. Pick up one shovel pack.

4. Take additional equipment as assigned by rescue leader.

5. Write down names of members in your party.

6. Proceed to accident according to the directions of the rescue leader. (It may be necessary to have witness accompany your column.) Flag trail if necessary.)

7. At avalanche site, evaluate the existing hazard and formulate the escape route. The escape route should be known by each volunteer in your column.

8. Post avalanche guard if necessary.

9. Make thorough surface search of slide area, including outside perimeter.

10. Mark victim's point of entry into slide path, last seen point, and any articles of clothing or equipment found.

11. Determine most likely burial region.

12. Work uphill.

    <u>Coarse Probe:</u> Feet shoulder-width apart. One foot between men. Probe once between feet. Move ahead 2 feet and repeat.

13. Brief First Column leaders as they arrive, as necessary.

14. As additional First Stage columns arrive, integrate manpower into larger probe lines.

15. Retain leadership until accident site commander arrives.

16. Brief accident site commander upon arrival.

17. Give accident site commander manpower lists.

Party Members

1. ______________________________
2. ______________________________
3. ______________________________
4. ______________________________
5. ______________________________
6. ______________________________
7. ______________________________
8. ______________________________
9. ______________________________
10. ______________________________

NOTES:

(The following information will be placed in an envelope. This envelope will be plainly marked: INSTRUCTIONS FOR COLUMN LEADER. Each cache will contain three of these envelopes. Also, pencil in each envelope.)

INSTRUCTIONS FOR COLUMN LEADER

With emphasis on speed and safety, proceed as follows:

1. Screen out volunteers who seem unfit for the operation.

2. Equip each volunteer with a probe.

3. Pick up one shovel pack.

4. Take additional equipment as assigned by rescue leader.

5. Write down names of members in your party.

6. Follow established route to accident.

7. Improve trail markings if necessary.

8. Upon arrival at accident site, follow directions of person in charge. (Either First Column Leader or Accident Site Commander.)

9. Turn over list of manpower to Accident Site Commander.

   Party Members:

   1. ______________________________
   2. ______________________________
   3. ______________________________
   4. ______________________________
   5. ______________________________
   6. ______________________________
   7. ______________________________
   8. ______________________________
   9. ______________________________
   10. ______________________________

INCLUDED IN PLAN BUT
NOT SHOWN IN THIS APPENDIX

1. Inventory of equipment in caches.

2. Maps.